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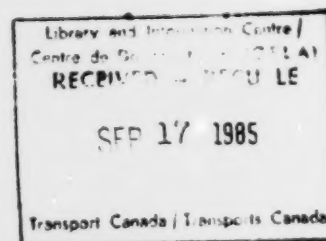


STRESS MEASUREMENT PROGRAM
MS COLUMBIALAND
1983 VOYAGE
FINAL REPORT
TP# 6257E

Prepared For:
Transportation Development Centre
Transport Canada
Montreal, Quebec

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The contents of this report reflect the views of the Contractor and not necessarily the official views of the Transportation Development Centre.

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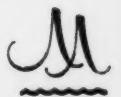
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17. Abstract Results from a ship hull stress monitoring program are presented. The instrumented vessel was an ice class bulk cargo ship travelling through the Arctic Canada Traffic Zone in October 1983. The work was performed jointly with a Swedish shipbuilding company. Details of the data acquisition system are presented and the data sampling strategy is discussed. Analysis of the raw data was performed by the Swedish partner and their report is reproduced in full. Specific ice impact incidents which resulted in high stress readings are analyzed and correlated to ice conditions at the time. Most of the gauges which recorded high stress levels were within 2 m of the waterline. The stress records suggested ice impacts were due to short duration point load forms rather than to loads distributed over a large area of the hull. The number of incidents in which significant stress levels were measured was small, even though ice conditions were very severe throughout much of the voyage. This was due to piloting practice, which was to sustain the least number of impacts with the lowest possible severity for any given ice conditions.					
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17. Résumé Ce rapport rend compte des résultats d'un programme concernant le suivi des niveaux de contrainte dans la coque d'un navire. Il s'agissait, en l'occurrence, d'un cargo brise-glace qui, en prévision du périple à accomplir, en octobre 1983, dans la zone de navigation arctique canadienne, avait été équipé d'une chaîne de mesure. La recherche s'est faite conjointement avec une société de construction navale suédoise. Le rapport décrit la chaîne de mesure ainsi que la méthode de traitement des données. L'analyse des données brutes a été faite par la firme suédoise dont le compte rendu est reproduit au complet. Celui-ci analyse les cas d'impacts ayant produit des contraintes élevées et les met en rapport avec les conditions glacielles observées. Il a été constaté que la plupart des signaux indiquant des niveaux de contrainte élevés proviennent de capteurs situés à 2 m ou moins de la ligne de flottaison. Les enregistrements indiquent en outre que les chocs étaient de nature ponctuelle et localisée, de courte durée. La fréquence des impacts provoquant des contraintes élevées a été plutôt faible, malgré les conditions glacielles difficiles qui ont perduré. Cet état de choses peut être attribué aux précautions prises par le capitaine qui cherchait à éviter au maximum les chocs durs et à atténuer, dans la mesure du possible, les chocs inévitables dans les conditions glacielles observées.			
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1. Introduction

During the 1983 voyage of MS Columbialand to/from Little Cornwallis Island in the eastern Canadian Arctic, information on ice loads and ice-transiting capability was collected aboard the ship. These structural data were obtained on an opportunity basis during a normal (commercial) passage of this merchant ship through the Arctic Canada Traffic Zone; they were not the result of dedicated trials, ramming tests, or other performance measurements. This report presents the findings of structural studies completed aboard the ship.

These studies were conducted by personnel from Martec Ltd. and Gotaverken Arendal AB (GVA). GVA is a major ship design, offshore fabrication and marine engineering company in Gothenberg, Sweden. Installation of strain gauge arrays, extensimeters, data acquisition systems, and other instrumentation equipment was GVA's responsibility. A joint Martec-GVA team operated this equipment in the field. GVA completed the preliminary analysis of structural data collected aboard the Columbialand; this work included processing, filtering, formatting, and production of stress-time histories, amongst other tasks. Martec was responsible for an assessment of selected loading events in the data record, an overview of the preliminary analysis completed by GVA, and a comparison of the structural information with ice conditions during the voyage.

Section 2 of this report explains some elements of the methodology applied to work in the field. Section 3 is a commentary on GVA'S structural analysis. In Section 4, ice conditions and piloting factors are discussed with respect to observations in the commentary. Concluding remarks are found in Section 5.

Appendix A contains the full text of GVA's report on the structural work, including their results from analyzing the 48 hours of data recording aboard the ship. We regard this information as an integral part of the present report; it furnishes many details about installation of equipment,



data sampling strategy, data retrieval, and operation of the data acquisition system, in addition to the preliminary analysis itself. Appendix B shows the general plan and arrangement of the Columbianland, relevant ship particulars, and ship performance data from her trials at ballast draft.

2. Methodology and Background Remarks

This section outlines some aspects of the shipboard work, and explains some circumstances that are relevant to the structural portion of the project. These comments will help to focus parts of the discussion in Sections 3 and 4, and augment some of the descriptions in Appendix A.

The studies conducted on the ship during the 1983 voyage were multifaceted. In addition to the hull stress measurements reported here, navigability and ship operations work took place concurrently. Two working papers, entitled "1983 Navigability Study, MS Columbialand" and "MS Columbialand, 1983 Voyage: Vessel Traffic Management and Icebreaker Assistance", present these results.

As part of the joint effort in the field, Martec contributed hardware and software to the data acquisition system installed on the ship. Specifically, we supplied one Hewlett Packard 7908R disk-tape drive for on-line data collection and off-line data storage; one Hewlett Packard 98624A computer interface; a number of Hewlett Packard 88140L high density data cartridges; and Hewlett Packard PASCAL 2.1 software used to write/compile programs that ran the data acquisition system. Also, ten strain gauges were purchased, bench-tested, and installed on the ship by GVA, with all costs to Martec's account. These items were essential and significant contributions to the project. In light of final equipment configurations in the field, the hull stress measurements could not have succeeded without the items we contributed to the project.

At a late date, prior to commencement of the charter, GVA informed us that real-time data collection would be software-limited to roughly 45 minutes of on-line operations. This 45 minute interval represented the contents of one full hard disk volume, organized into 15 directories of 65 records each, 15.85 Kbyte (or 7800 values) per record. The disk was programmed to store data values from 39 channels sampled simultaneously at a nominal frequency of 75 Hz, yielding individual records about three minutes

in length. The 67 Mbyte mass storage media used for tape backup accepted four full hard disk volumes; it took approximately 30 minutes (off-line) to transfer the contents of one hard disk to the streaming tape drive. It was not possible to write these data directly to tape media. In the field, where the data acquisition system was under full operator-control, it was possible to select continuous recording for 45 minutes, or any three minute set of increments that summed to this total. In other words, the system could run for six minutes, then for nine minutes, then for 30 minutes, for a total of 45 minutes on the hard disk, before the off-line transfer to tape was necessary.

By exercising judgement about when to operate the system (usually, by selecting ice conditions with a high likelihood for impacts present), some 80 to 90 percent of all impacts sustained by the ship took place when the system was on. This careful choice of on-line time offered the possibility of relatively good data return, that is, if any data were sampled to begin with. We could not, of course, predict when impacts would be sustained on that part of the hull on the port side of this ship that was instrumented, or what the magnitude of these impacts would be when they took place. This was a major constraint on our work.

3. Hull Stress Measurements

This section of the report summarizes the results of the hull stress measurements obtained during the 1983 voyage to/from Little Cornwallis Island. GVA conducted the analysis of the raw data, as described in Appendix A. Section 3 is not an assessment of this raw data, but rather, a discussion of the results reported by GVA. All references to figures and diagrams comply with those in the GVA document, unless we note otherwise.

The GVA report (Appendix A) has presented the results from the analysis in two different ways. The first approach considered the recorded impacts in a statistical manner, noting the number of times each gauge showed a response, and the magnitude of that response. This method does not provide any information about the impacts with respect to their time of occurrence, but does indicate which gauges have obtained the most information and what stress levels were obtained. The second method presents the stress response of several gauges for the same period in time, particularly during a heavy ice impact. This provides some indication of how the structure is responding to the load, and how each of the structural elements behaves. This is the type of information required for comparison with, or validation of, an analytical model of the ship.

Before we review the data analyzed by GVA, consideration should be given to the type of structural elements on which the strain gauges were mounted. Some attention should be given to the orientation of these gauges with respect to expectations about how the ice loading will be carried through the ship. The load carrying system consists of three different types of structural elements; these are the hull plate, the frames, and the longitudinal stringers. The ice load is applied at the exterior of the hull plate, which carries the load to the transverse frames. These frames are closely spaced members oriented in a vertical plane to follow the hull form. The frames are supported by the stringers which are horizontal plates running in the lengthwise direction. Note that a stringer (a term taken from the GVA report) is perhaps more aptly described as a deck. However, to

remain consistent with the GVA report, the term stringer will be retained. The strain gauges installed on the ship were all single axis gauges, which means they will measure the stress in only one direction. Thus, the location and orientation of a gauge will affect the way in which the gauge responds to a particular load.

All gauges on the hull plate were mounted mid-way between adjacent frames, and oriented to measure the strain in the direction perpendicular to the frames. The vertical location of these plate gauges varied; some were mounted close to stringers, and others were mounted more or less mid-way between stringers. The location of a gauge with respect to the stringers will affect the responsiveness of the gauge. A section of the hull plate bounded by two adjacent frames and two stringers will give a plate with a large aspect ratio, where the direction of the major stress component is in the short direction (i.e., in the direction of the strain gauges). Thus, the hull gauges mounted mid-way between stringers were mounted to measure this major stress component. These gauges should have been quite responsive to local loads, recording a fairly high stress level for a well-defined period of time. However, gauges mounted close to stringers are expected to be less responsive, recording only very local loads, as the stringers are relatively very stiff and will normally carry most of the load.

Gauges on the frames were mounted on the frame flanges, in the direction of the frame, mid-way between stringers. This positioning allowed for identification of any bending in the frames. Gauges were located on the stringers in such a manner as to measure the maximum stress due to bending of the stringer in the horizontal plane. However, due to the complex geometry of the bow structure where the stringer gauges were located, results from these gauges are best interpreted as indications of impact severity, rather than any kind of simple bending response to the ice impact.

Gauges which recorded no impacts are shown in Figure 21. The gauges included both of the extensimeters and three of four gauges mounted on stringers in the aft body. The lack of data from the extensimeters is

explained by consideration of the reason for installing them on the ship. They were intended to measure the over-all bending moment in the hull; it would require a very heavy impact to stress them significantly. There does not appear to be any evidence for impacts of this magnitude in the data record. We mention that the ship was seldom piloted in ramming mode during the 1983 voyage; severe impacts were not sustained during any operations of this type. The stringers in the aft body of the Columbiand are quite rigid structures; similarly, it would have taken a very heavy impact to stress these gauges significantly. Furthermore, this area of the ship is not expected to sustain a large number of impacts, thus decreasing the likelihood for a severe impact to take place.

Of the gauges installed forward, hull gauges 7, 13, and 22 showed no record of impact. However, these gauges were only sampled during the ballast (inbound) portion of the voyage, and even then, were at least 2 m below waterline, factors which would decrease the probability of their registering an impact. Gauge 29, mounted on a stringer, also recorded no impacts. This could be due to the fact that the stringer, being a very stiff structural element, would have to sustain a substantial impact in order to record a significant stress. In addition, this stringer was not at either the ballast or loaded waterline, and thus, less likely to sustain direct impacts. We believe that very little can be concluded from the remaining gauges which recorded no impacts, especially since two of the gauges (9 and 37) were adjacent to gauges which recorded impacts greater than 40 MPa. Of course, it may be that a hardware failure (for example, strain gauges not bonded adequately, wiring connections not secure, etc.) can account for the lack of data recorded from any or all of these gauges.

Figures 13 to 16 indicate the percentage of time that each gauge recorded an impact in two different stress levels, at both ballast (inbound) and loaded (outbound) draft. Figures 15 and 16 illustrate the impacts in stress level 1. Each stress level corresponds to about 32 MPa, which is approximately 10% of the yield stress of the steel (355 MPa). Figures 13 and 14 show impacts greater than 40 MPa. Thus, these four figures describe

nearly all of the impacts recorded during the 1983 voyage. Figure 12 divides the gauges according to whether or not they recorded stresses in excess of 40 MPa at both loaded and ballast draft. This diagram is more or less a summary of Figures 13 to 16. For both the loaded and ballast condition, high stress levels are shown only in the plate and frame gauges. These were located very close to waterline, in most cases, within 2 m of it. Of the plate gauges recording stresses greater than 40 MPa, all but one were much closer than 2 m to waterline. This may be due to two factors. First, the loading itself may be of a very local nature; or second, the load is carried very quickly from the plate into the frame, either of which would show a very local effect in the response of the gauges. Frame gauges that recorded stresses in excess of 40 MPa were not as close to waterline as the plate gauges; this was a function of their position, since generally, frame gauges were not located at or on the waterline as were the plate gauges. However, the results still indicate a localized nature of loading, concentrated near the water line.

Examination of the stress-time plots in Figures 8 to 11 suggests how the ship structure is carrying the load, and emphasizes the localized nature of the load. Although these plots do not have a scale indicated, peak values of stress are shown. Many of the individual stress-time records presented in these figures are repeated in more detail in Appendix A of the GVA report, as well as some records which are not used in Figures 8 to 11. Based on the information presented in the GVA report, it appears that the only gauge to record a permanent strain after an impact was the gauge on the hull plate as indicated in Figure 10.

Figure 8 shows impacts at two plate gauges separated by about 2 m; there is virtually no overlap of the stress records. That is, as one gauge recorded a stress, the other showed very little stress; the converse also applied. The response of a frame near one of these plate gauges was somewhat slower than the plate, in that it responded over a longer period of time compared to the plate. This may be due to the frame carrying a load from a larger area than the plate, but it nevertheless showed very little

response when the second plate gauge was recording its peak stress. Figure 9 illustrates very similar findings, with the plate gauge showing a quite peaked response when the frame and stringer gauges recorded a lower level of stress for a somewhat longer time.

The plots in Figures 8 and 9 suggest that the ice load is a point type of impact applied quite suddenly and then removed, rather than a continuous load being spread along the hull at waterline, or a point load rapidly applied and then maintained as the ship continues her transit through ice. A continuous load should produce a gauge response over a much longer period of time than evident in these figures. Given the ship's indicated speed and approximate structural dimensions, the time interval between the forward-most and aft-most gauges in these figures is about 3 seconds. Therefore, if the load was applied at a point fixed in space, with the ship moving past it, the peak response of the extreme gauges should be separated by about 3 seconds. This does not appear to be the case, since all the gauges were responding at about the same time.

Figure 11 shows that same type of behavior. The indicated speed and approximate structural dimensions suggest that the time separation between the extreme gauges was about 2.5 seconds, but the gauges all indicate a response at roughly the same time. This diagram also provides insight into the load-sharing nature or characteristics of the framed hull structure, as only the two central frame gauges recorded much response, yet there were four frame gauges present along a 5 m section of the hull. This data suggests that any load applied to the hull is very quickly carried to the stringers, not distributed amongst a large number of frames when the ship sustains an impact.

Figure 8 is somewhat unusual in that the response of the forward-most gauge was recorded at a later point in time than the response of the aft-most gauge. The lack of crossover in the response again suggests a short duration point load type of impact, with very localized effects on the structure. This apparent inconsistency in the stress-time responses

suggests that two impacts took place.

Figure 10 shows some of the characteristics expected from a point load that remains stationary in space. Given the ship's speed and approximate structural dimensions involved, a time of about 0.75 seconds should elapse between the responses recorded at the forward-most and aft-most gauges. This appears to be the situation between the forward plate gauge, which eventually yielded, and the aft frame gauge, which recorded a peak stress of 290 MPa. However, the plate gauge next to this frame showed very little response. This disparity could be due to the orientation of the gauge and its proximity to the stringer. The stringer, a much stiffer structural element, would carry most of the load in this instance.

Figure 24 suggests that the duration of most impacts was usually 0.2 to 1.0 second. From the stress data in the GVA report, it appears that the rise time was normally about half the duration of an impact recorded at the strain gauge.

4. Ice Conditions and Piloting Factors

As noted earlier, ice conditions during Columbialand's 1983 voyage to/from Little Cornwallis Island are discussed at length in a companion report. This ice information was collected from the perspective of navigability and ice pilotage in Arctic waters. However, it was obtained using protocols that enable (some) comparisons with the hull stress data recorded during the voyage. This section presents these comparisons; some aspects of the late-season ice regime crossed by the ship are also discussed.

The 1983 shipping season in the eastern Canadian Arctic was characterized by very difficult ice conditions, particularly toward the end of this period, after freeze-up began. Cold temperatures and rapid formation of new ice caused (or promoted) further consolidation of existing old pack in Resolute Passage, McDougall Sound, Barrow Strait, and Lancaster Sound. The close to very close old pack with glacial inclusions often present by late-season at or off the entrance to Lancaster Sound was more concentrated than normal, and started to consolidate somewhat earlier than usual. This old ice from the Lincoln Sea, Nares Strait and Kane Basin (when present) poses the greatest risk to shipping of any ice type found in eastern Arctic waters. It is frequently organized into belts or strips of very close to compact pack, and often, subject to moderate or high pressure. Many merchant ships which are ice strengthened to a relatively low ice class (such as Columbialand) make slight way with only very great difficulty in this ice, if it can be crossed at all. Icebreaker escort at close quarters is often necessary under these ice conditions. Slow to dead slow transit is generally prudent, if not the norm, for merchant ships in this or any other type of concentrated second year or multi-year pack.

Since both frequency and severity of impact typically increase with ship's speed in heavy ice, it is not difficult to understand why relatively few impacts of any significant magnitude occurred during the 1983 voyage. Simply put, the ship was piloted at the lowest possible speed required to

maintain way and some measure of maneuverability in all concentrations of heavy ice encountered during the passage. This operational circumstance was good seamanship from the owner's perspective; it did not lend itself to extended collection of interesting impact data on the ship. The influence of competent pilotage in ice-covered waters on the magnitude and number of ice loads during the 1983 voyage is quite clear, and cannot be over-emphasized.

Impacts of interest from the structural point of view were not commonplace during the voyage, as discussed in Section 3. We focus our attention on the ice regime crossed by the ship during the impacts shown in Figures 8 to 11. The ice descriptions appended to each diagram are not definitive. These brief comments were attached for reference purposes only. The indicated speeds at the time of impact show good conformance with speed data in the navigability records, without exception. Maneuvers at close quarters were observed in each instance.

The episodes in Figures 8 and 9 took place within 5 minutes of each other, during an extended crossing of very close old pack in eastern Lancaster Sound. Glacial inclusions were present at trace concentrations in this ice. The ship was escorted by icebreaker during this part of the inbound voyage. By virtue of moderate to high ice pressure at the time, the cover was continuous ahead of the ship. It appears that the impacts shown in Figures 8 and 9 occurred in a brash and cake-filled icebreaker track the ship was transiting at dead slow speed. The ice in-track, and to 1/8 mile on either side of the track, was 9+ to 9:10 cover (mostly multi-year, as opposed to second year). Other impacts of similar magnitude were sustained by the ship before and after the events in Figures 8 and 9. Slight impacts also took place on a constant basis during this period.

The ship was transiting a belt of close old small floes in Resolute Passage when the impact shown in Figure 10 occurred. Close maneuvers through the belt at slow ahead were in progress at the time. The ship was assisted by icebreaker during this portion of the inbound voyage. It

appears that the impact was sustained in-track; light to moderate ice pressure was present in the belt. Slight impacts took place continuously in this ice; heavy impacts were sustained stbd and port side after the impact in Figure 10. Grey-white and ridged first year ice in the belt increased the total cover to very close or compact.

The impact in Figure 11 occurred in a navigable fracture through close to very close old pack with glacial inclusion in central Lancaster Sound. The ice in this lead (roughly 50 m wide at the time) was open to close old cake and occasional small floes. The ship was not assisted by icebreaker during this part of the outbound voyage. At least 3 other heavy impacts took place with ice in this lead, which the ship later retreated from when it began to close. Forward speed at time of impact may have been lower than the 3.6 kt indicated in Figure 11, since the engine rpm was no higher than dead slow ahead during the episode.

We now offer comment on ice conditions present during the impact shown in Figure 17. This impact produced strain above yield; it appears to have caused either permanent set of the plate the gauge was bonded to or permanent strain in the gauge itself. The ice described earlier, for Figure 10, was still present some minutes later when the Figure 17 event took place. The ship was following the icebreaker at the time; the impact appears to have occurred in-track. Since no impacts perceived as "severe" on the bridge were sustained in this belt, we conclude that the strain above yield was caused by a heavy port side impact.

The two compartment rupture sustained by the ship on the inbound voyage are not addressed in the GVA report. These damages were slightly below waterline at ballast draft on the shoulder stbd side. To the best of our knowledge, there is no evidence in the stress measurement record of the collision that would have caused the damages. All gauges, of course, were installed port side. There was no expectation at the time that any strain from stbd impacts would be carried or transferred through the hull to any gauging on the opposite side of the vessel. It is supposition to describe a

specific time and a specific ice regime for the impact. In fact, it does not appear to be possible to do this. However, expert opinion during repairs at Little Cornwallis Island focussed on multi-year cake or floe ice as the ice that caused the rupture. If we presume that collisions perceived as "severe" on the bridge are capable of causing damage, and that multi-year ice is the type of old ice necessary for these impacts, then the damages occurred during one of the four severe impacts sustained in close to very close multi-year pack on the inbound voyage. The ship was under escort during all of these instances, two in Resolute Passage, one each in eastern Lancaster Sound and central Lancaster Sound. Engine rpm, in-track, was dead slow to slow ahead.

Ice conditions during the 1983 voyage, we believe, were very severe. The ship was piloted with great caution at dead slow to slow speed in all heavy concentrations of old or first year ice. This type of ice, the regime most likely to cause significant impacts, was crossed by the ship as a last resort. Maximum avoidance of these ice conditions was clearly the standard piloting procedure.

5. Conclusion

This report describes work on ice loads and impacts during the voyage of MS Columbiand to/from Little Cornwallis Island in September-October 1983. A preliminary analysis of these data (attached to this document at Appendix A) is the subject we discuss in Section 3. Ice conditions and piloting factors pertinent to these remarks on the hull stress measurements are described in Section 4. In this section, we present some conclusions about the work, and the circumstances of conducting structural studies aboard merchant vessels time-chartered for commercial purpose in Arctic waters.

Our assessment of the preliminary analysis was restricted to selected portions of the processed stress data, in accordance with the terms of reference on the project. These results indicate that most of the ice impacts were sustained very close to waterline, usually within 2 m of this mark. Impacts recorded by the stress measurement system appear to be point form loads, rather than loads distributed over a large area. They also appear to be of short duration. This description of the nature of loading is based solely on the data available from the 1983 voyage, and should not be construed as typical of all ice loading in ice-covered or ice-infested waters. Finally, the ship structure itself appears to be very local in its response, such that gauges not far from the impact point display very little response.

A strain gauge array, such as used on the Columbiand, allows data to be collected for impacts over a very large area of the hull at and below waterline. It is also useful for qualitative assessment of the loading response, as we presented in Section 3. However, for any type of quantitative analysis, especially one which is related to an analytical or numerical model, it would be desirable to have a much higher (or denser) concentration of strain gauges installed on structural elements. This necessity is due to the localized nature of the load, and the structural response imparted by this load. Our review of the preliminary analysis

leads us to conclude that the gauges on the hull plate should have been concentrated near the waterline, and more of the frames should have been instrumented in order to better define the spatial distribution of the load.

The ice conditions encountered by the ship during the 1983 voyage offered great potential for good data collection. The inbound/outbound ice regime off the entrance to Lancaster Sound, particularly, was very nearly the "worst case" late season situation. This was also true in the Sound itself, and in sections of Barrow Strait and Resolute Passage. However, in addition to the presence of the appropriate ice conditions, relatively high ship's speed is essential for statistically valid, large magnitude ice impact data. Generally speaking, these high speeds were not used by ship's officers to transit any of the moderate to heavy concentrations of ice encountered during the voyage. In other words, the very combination of ice conditions and piloting factors that leads to large number of significant impacts is the least acceptable one from the master's or owner's point of view. As a result, relatively few impacts were sustained by Columbiand on the 1983 voyage for the ice conditions en route, since slow to dead slow speeds were invariably used to transit heavy pack, if this ice could not be otherwise avoided, and had to be entered as a last resort. Once in this ice, the ship was piloted with very great caution. Normally, rather than ramming and backing, the ship used leads, cracks or fractures to the greatest extent possible, making way by pushing cake and floes apart. If ice conditions were perceived as simply too difficult, the ship was taken astern, the intent being retreat from the area.

We must emphasize that the hull stress measurements were conducted on an opportunity basis aboard the ship. The ship was not chartered for dedicated ice trials or ramming tests during the voyage; commercial purpose was the only clear motive controlling the ship's transit of eastern Arctic waters. We had no influence over the route used through these waters, the ice conditions along this route, and most importantly, the speed or maneuvers in this ice. By operating the data acquisition system at what appeared to be the most opportune times, we ensured that a maximum amount of

ice impact data would be collected if impacts were sustained by the ship. This was clearly the best, though only, approach we could take aboard the ship for the stress measurement program. It was the one dictated by the normal considerations of all commercial charters. Safe passage through the lowest possible concentrations of ice takes precedence at all times during these voyages; sustaining impacts with heavy ice, at any speed, under any circumstances, has very low priority.

The true role of these normal piloting considerations was not fully known before the voyage began. The prevalence of maximum ice avoidance in most Arctic regions was somewhat greater than expected. An optimum routing strategy in ice-covered waters, normally the most cost-effective operation from an owner's point of view, was not particularly obvious during the 1983 voyage. The stress data record contains large amounts of low to very low level ice load information, a situation much in line with standard piloting procedures aboard the ship. The lowest possible speed needed to maintain way and some degree of maneuverability appeared to be always used in close pack or more concentrated cover. The object of this piloting practise was clear - sustaining the least number of impacts of lowest possible severity in ice of any given concentration crossed by the ship.

We conclude that relatively low ice class merchant ships on commercial charter in Arctic waters may not be the most suitable platforms for stress measurement programs. However, it is clear that important data was collected aboard the Columbiand in September-October 1983, and that valuable insight on the nature of loading during impacts resulted. The technological transfer related to instrumentation techniques and design of data aquisition systems was significant in this regard. Though the stress measurement program was ultimately, and unavoidably, constrained by ice piloting practises used aboard the ship, we believe that our findings were useful and relevant, and that the project itself was very successful.

APPENDIX A
GVA REPORT ON STRUCTURAL STUDIES



HULL STRESS MEASUREMENTS
ON M/S 'COLUMBIALAND'
OCTOBER 1983



1984 - 08 - 20



GVA

Götaverken Arendal AB



HULL STRESS MEASUREMENTS ON M/S "COLUMBIALAND"

1 - Introduction

Full scale measurements were performed on the Swedish flag bulk carrier M/S "COLUMBIALAND" on a trip to Little Cornwallis Island in the Canadian High Arctic, October 6-15, 1983.

The vessel was bound for POLARIS NINE to load zinc and lead concentrate for export to Europe.

The ice conditions on the voyage were not severe and for part of the voyage "Columbialand" was assisted by the Canadian icebreaker "John A. MacDonald".

Only a small number of impacts were recorded. However, knowledge about ship performance in ice was gained by studying the character of the ice impacts on the ship's hull.

The instrumentation system is briefly described below, followed by a summary of the most important results from the analyzed hull stress data.

Appendix A is a summary of plots for the most important impacts.

Appendix B contains some explanation to print outs and typical examples.

2 - The Instrumentation System

The instrumentation system installed on board "Columbialand", recorded following data:

- hull stresses from 30 gauges mounted mainly in the bow
- thrust, torque, rpm and speed
- rigid body motions
- ice conditions

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2

The system is designed for measuring strains in the hull structure for comparison to speed, thrust and ice conditions.

Signals were sampled in a digitalized form by a computer and stored on a Winchester hard disc. The completely filled data set on the hard disc was then transferred to a tape.

2.1 - Strain Gauges

A total of 38 strain gauges were installed. Different sets of gauges were recorded reflecting the vessel's loading conditions, ballast or fully loaded. The location of gauges and correlation to computer channels can be found in figures 2-6.

All gauges were cemented to the hull and all cabling was waterproof.

2.2 - Propulsion System

Strain gauges were installed on the shaft for measuring torque and thrust. The signals were amplified and transmitted from the shaft by means of telemetric apparatus. For rpm measurements, photocell equipment and a tachogenerator were used.

2.3 - Computer System

This system utilizes one HP 9836A computer, one HP 2671G printer, one HP 6940B multiprogrammer and one HP 7908R disc/tape drive for storing data. The program language is PASCAL.

The system samples 39 signals simultaneously with a frequency of 75 Hz, i.e. 2925 values/second are processed. The range of each signal is divided into 32 levels (+/-16). Thus each level for the strain gauge signals corresponds to 32 N/mm².

2.4 - Video

The video system consists of two independent video units. One camera for recording the ice conditions ahead of the vessel and one side looking camera for ice thickness estimating.

The complete instrumentation system and layout are shown in figures 1 and 7.

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3 - Test Results

The resulting force from an ice impact is acting on a very small area of the hull. A heavy impact at a certain location on the hull, can cause high strain at that very point, while other points nearby only have low strain. See figures 8, 9, 10 and 11.

Because it is easier to deal with stress (MPa) instead of strain, the results are presented in stress tables. Stresses above the yield stress 355 MPa will not occur but can be converted to strains by the factor $1/E$ (E = Young's Modulus).

The analysis of the data shows clearly, that the heavy impacts are mostly found close to the waterline. See figures 12, 13 and 14. This reflects the fact that a large bulk carrier operating in pack ice hardly breaks the ice but pushes it aside. The forebody is certainly the most exposed area to ice impacts. Especially exposed on Columbiand is the area surrounding the collision bulkhead. Even for small impacts (stress level 1) similar conditions are prevailing. See figures 15 and 16.

The measured impacts in this level counts for about 85 percent of the total number.

On one occasion the ship had a heavy impact as low as 4 metres below the actual waterline. The rest of impacts were distributed +/- 2 meters from the waterline.

The highest recorded strain corresponds to a stress of 500 MPa. This strain was recorded in the shell plate for gauge No. 31. Following the impact a permanent strain of 300 MPa was recorded at the very same gauge. See figure 17.

The duration of the heavy impacts is often in the interval of 0.25 to 1.0 second.

One can also note a faster response in the plating than for the frames and stringers. See figures 8, 9, 10 and 11.

The gauges on the plating also show a negative strain before and after the ice impact. See figure 18. This is due to the fact that surrounding plate panels are also stressed.

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When the ship is steaming in close pack ice or in thin level ice, the ice floes are sliding along the ship's side, resulting in a rather random distribution of ice impacts. Although the number of gauges is limited, one can see that a sliding ice floe causes only a few local impacts.

List of remaining figures:

Figure 19: Table of impacts ≥ 40 MPa

20: Table of impacts in stress level 1

21: Gauges with no impacts during the voyage

22: Stress level as function of number of exceedings

23: Stress level as function of duration of impacts

24: Percentage of total number of impacts as function of duration of impacts

1984-08-20/GL

MS 'COLUMBIALAND' - Instrumentation

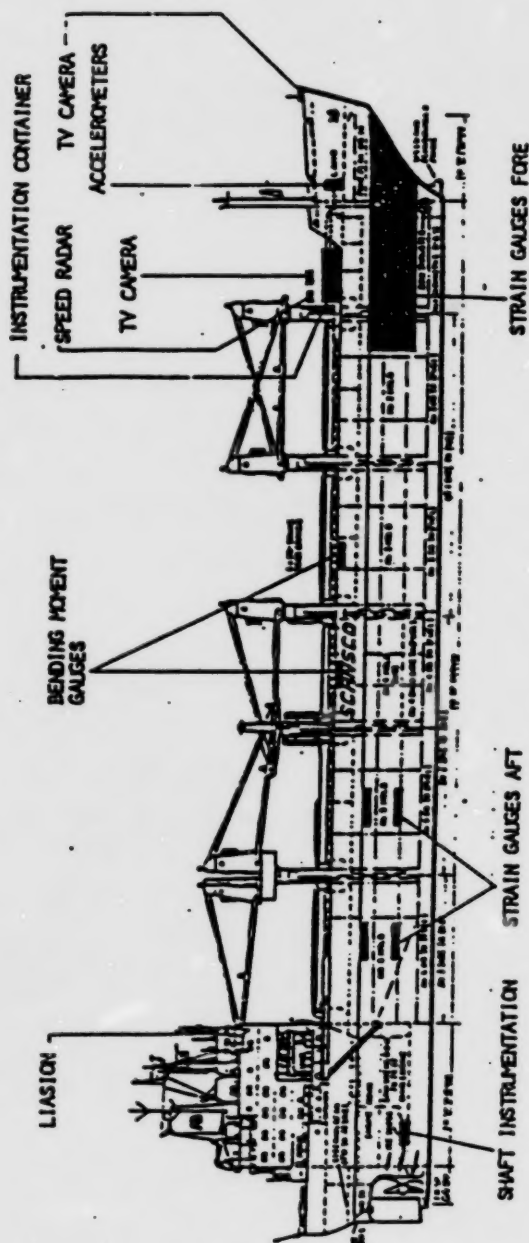


Fig. 1

MS COLUMBIALAND - INSTRUMENTATION PLAN.

M

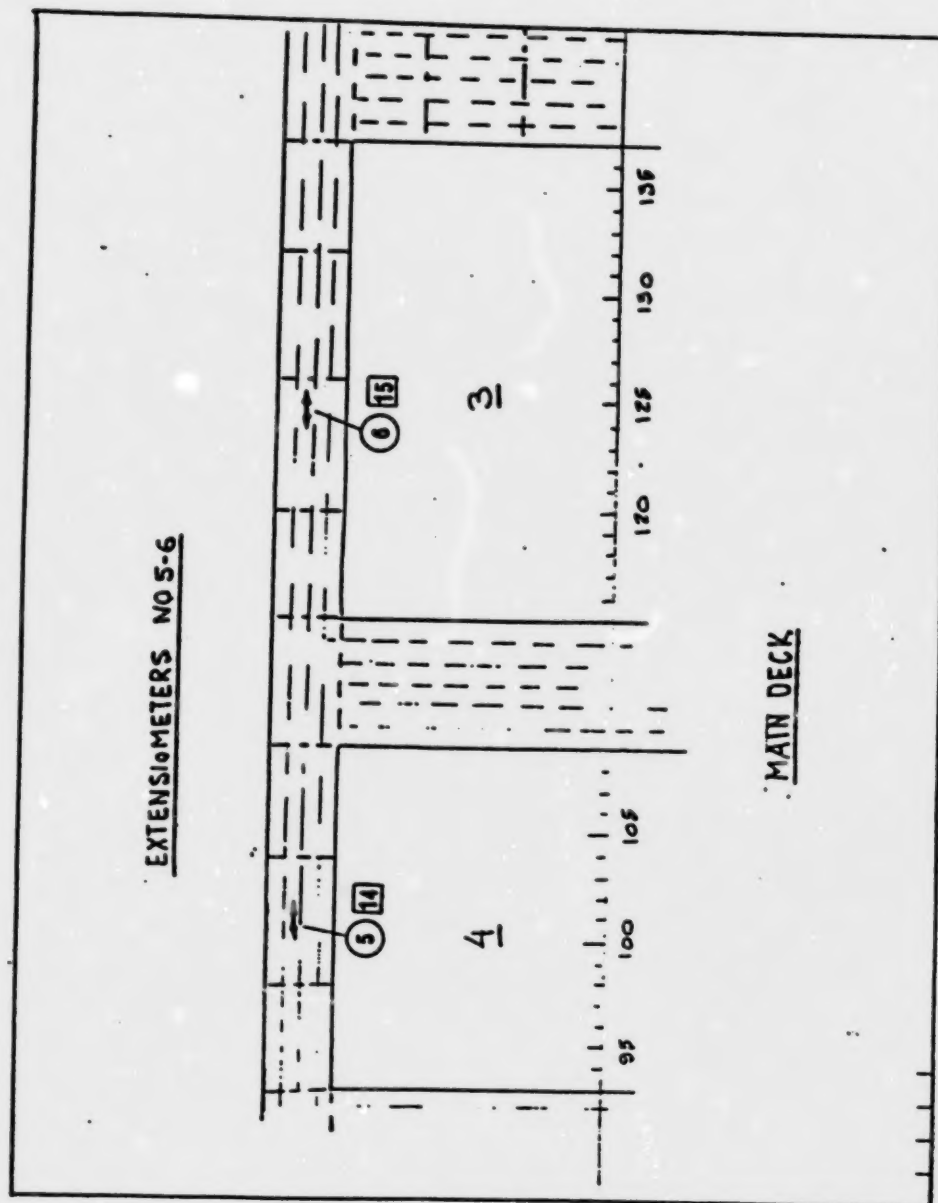


Fig. 4 GAUGES FOR MEASURING THE OVERALL BENDING MOMENT.



GVA

Generalized Variable Amplifier

COMPUTER CHANNEL			
1	Computer ON-OFF > 4 V		
2	Torque 0-10V $\approx$ 0-10 ⁶ Nm		
3	Thrust 0-10V $\approx$ 0-1,5 $\cdot$ 10 ⁶ N		
4	RPM 0-4V $\approx$ 0-100 rpm		
5	Acc X 1V $\approx$ 1G		
6	" Y		
7	" Z		
8	Speed 10V $\approx$ 15 knots		
9	Spare		
		GAUGE No. BALLAST	GAUGE No. LOADED
10		1 10V $\approx$ 500 MPa	31
11		31	2
12		3	32
13		33	4
14		5	5
15		6	6
16		7	33
17		8	34
18		9	9
19		10	10
20		34	11
21		35	12
22		13	35
23		14	14
24		15	15
25		16	16
26		17	17
27		36	18
28		19	36
29		20	20
30		21	21
31		22	37
32		23	23
33		24	28
34		25	25
35		26	26
36		27	27
37		28	28
38		29	29
39		30	30

Fig. 6 COMPUTER CHANNELS CORR. TO GAUGES.

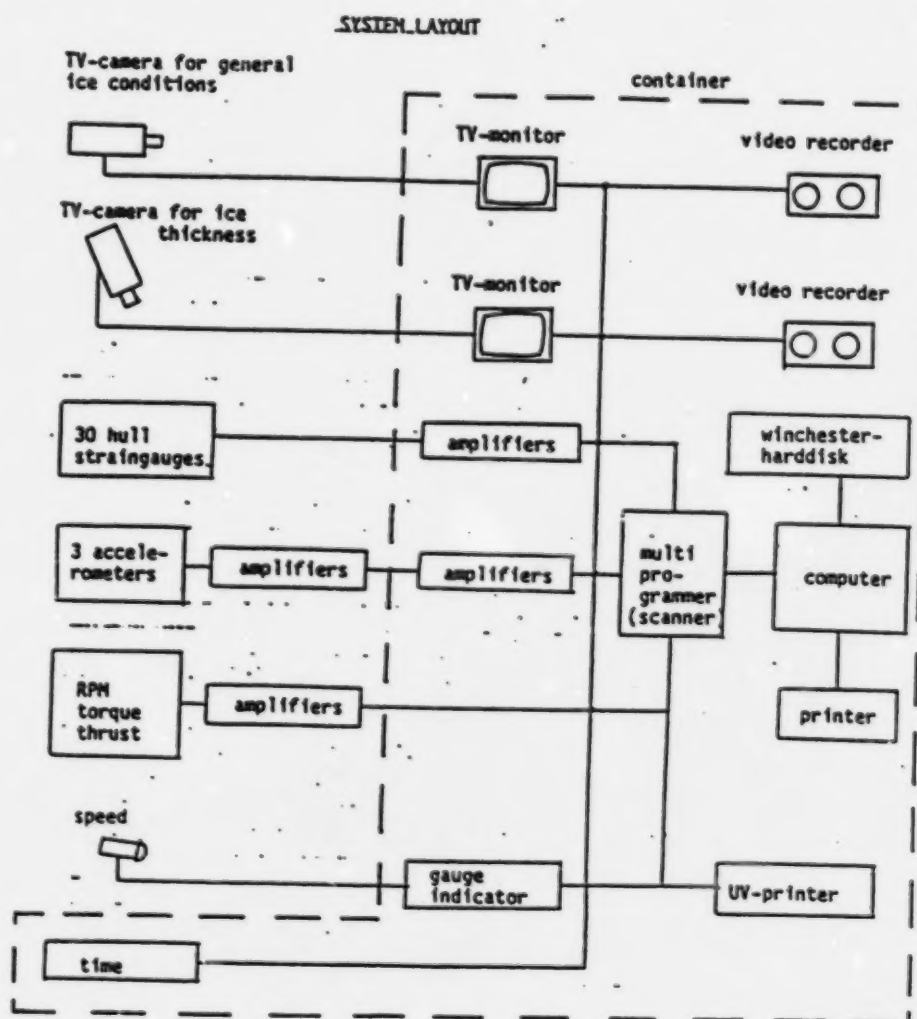


Fig. 7 SYSTEM LAYOUT.

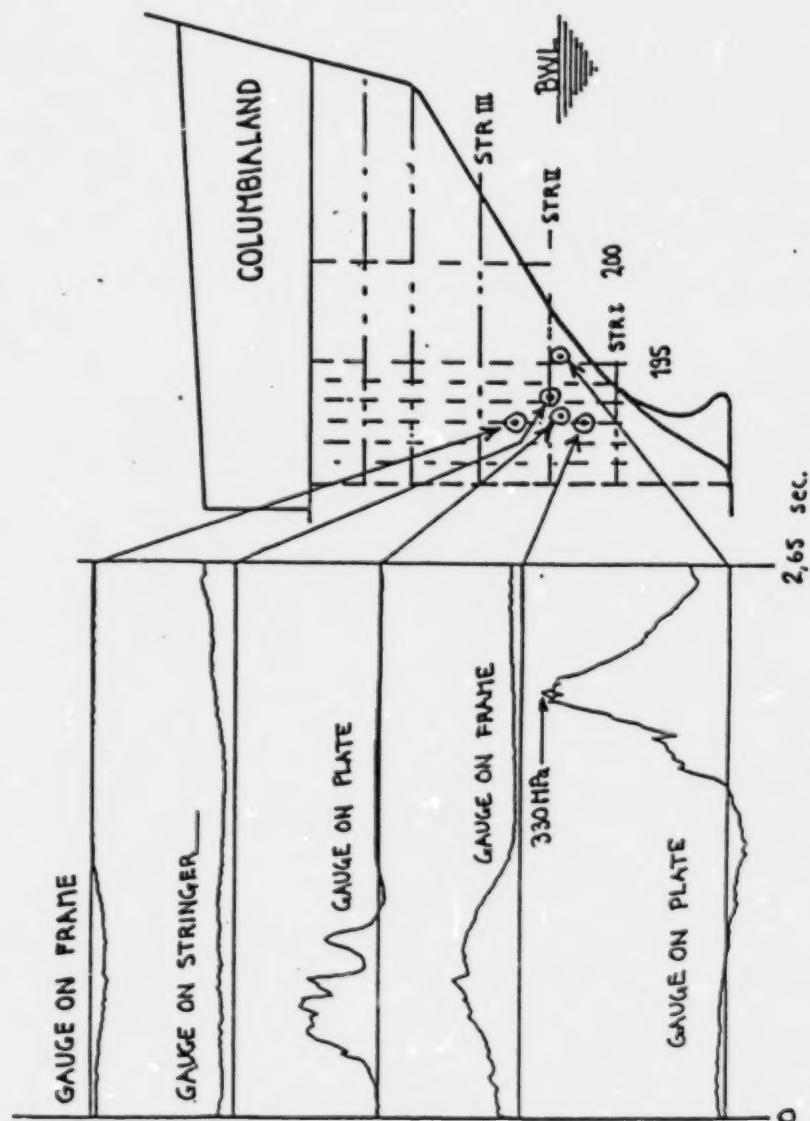


Fig. 8 A HEAVY IMPACT 83-10-05 , RUN 8 , VOLUME 13 , RECORD 1 ,
SPEED : 1,3 Knots
ICE : 7/10 MULTI YEAR ICE

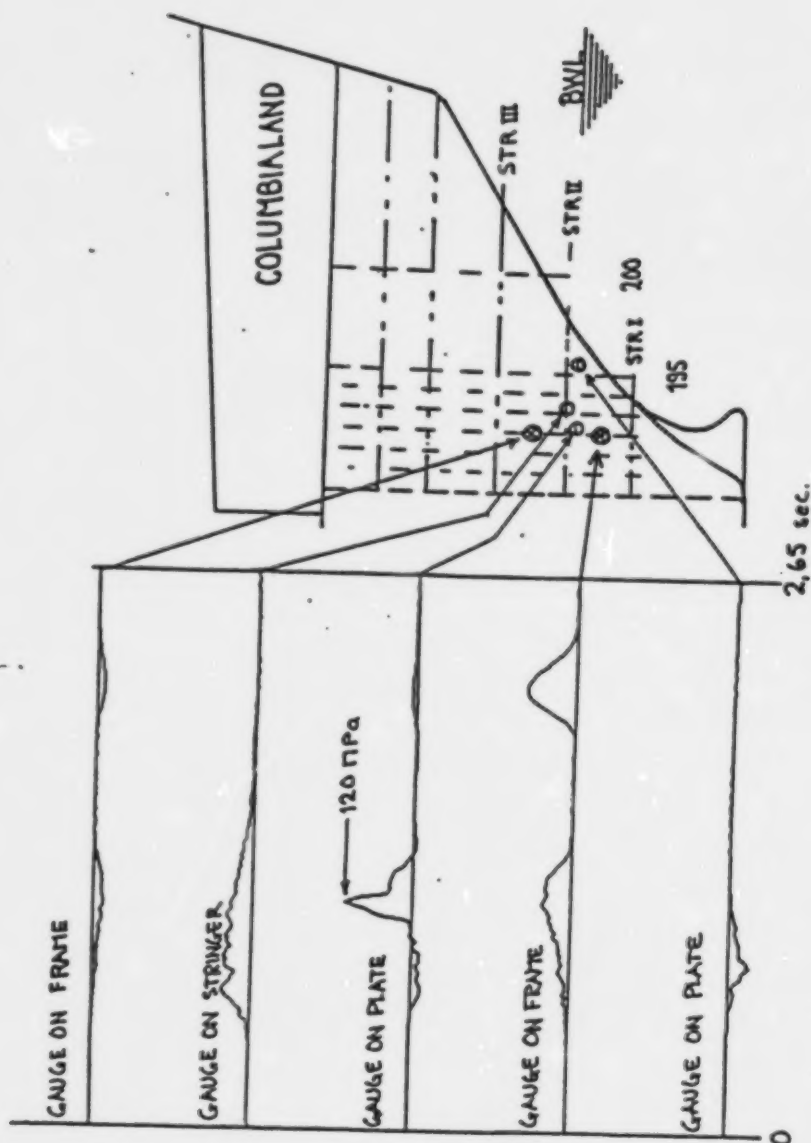


Fig. 9

A HEAVY IMPACT 83-10-05 , RUN 8 , VOLUME 14 , RECORD 17 ,
SPEED : 1,3 Knots
ICE : 7/10 MULTI YEAR ICE

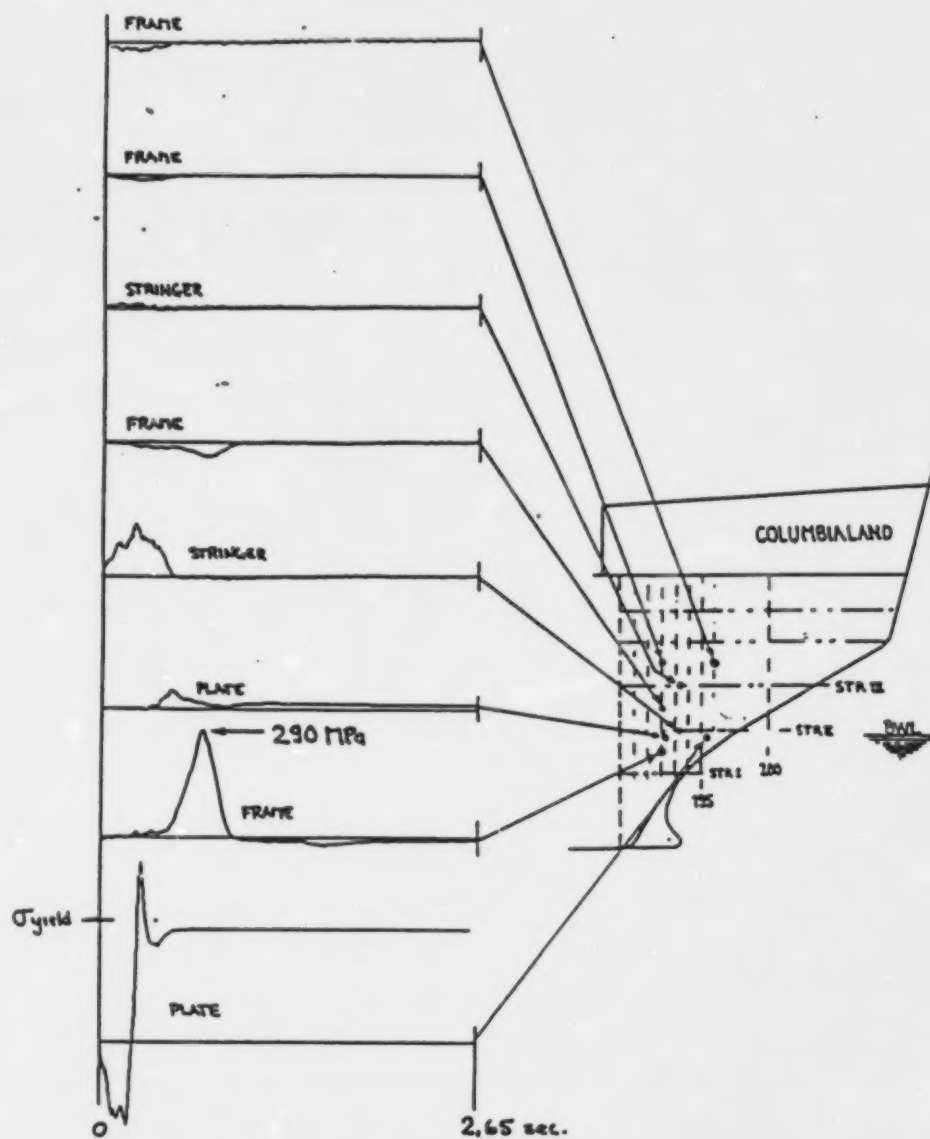


Fig. 10 A HEAVY IMPACT 83-10-06 , RUN 18 , VOLUME 13 , RECORD 49 ,
SPEED : 5,5 Knots
ICE : SOME HEAVY ICE IN AREA

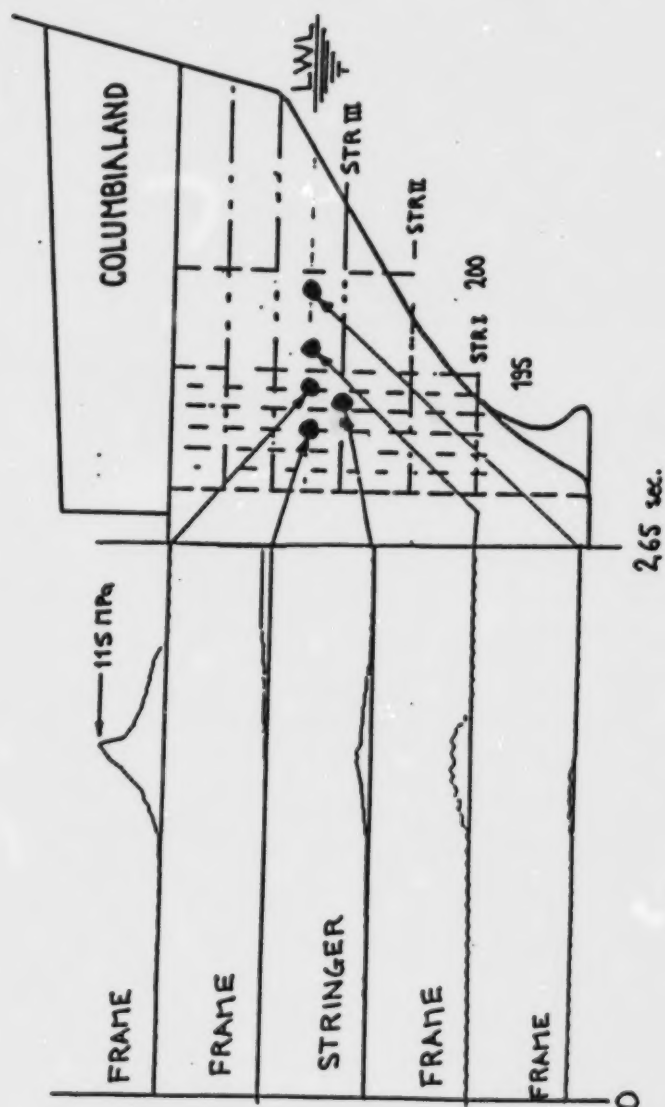


Fig. 11 A HEAVY IMPACT 83-10-12 , RUN 49 , VOLUME 15 , RECORD 11 ,
SPEED : 3,6 Knots
ICE : BIG PIECES OF MULTI YEAR ICE

GVA
Gauging and Vibration Analysis

- GAUGES STRESSED ABOVE 40 MPa.
- GAUGES NOT STRESSED ABOVE 40 MPa.

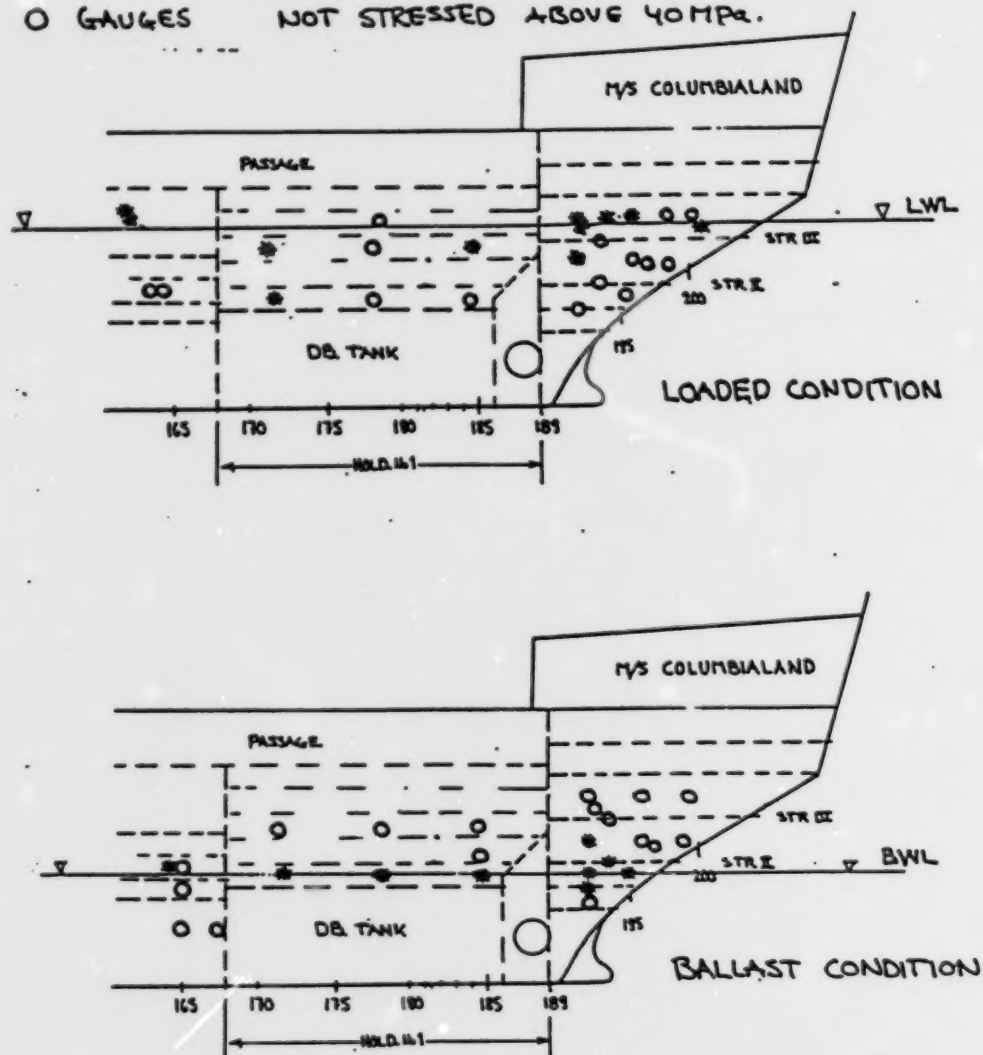


Fig. 12

RECORDED IMPACTS DURING THE VOYAGE.

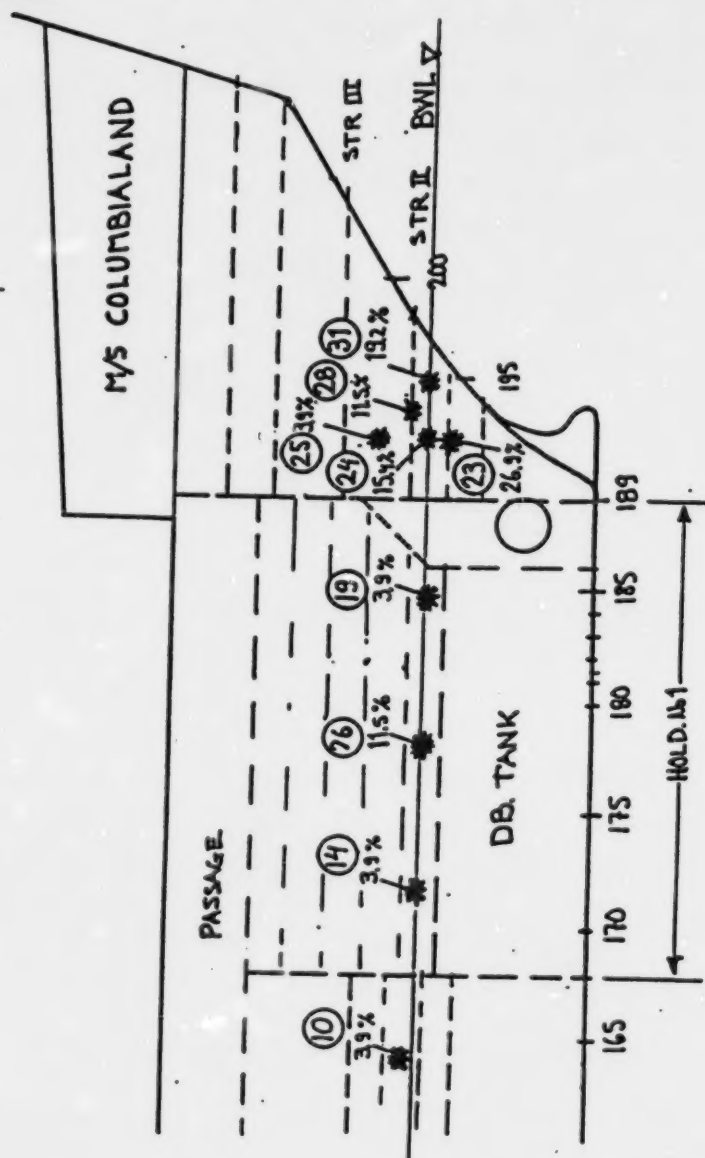


Fig. 13

* IMPACT ≥ 40 MPa BALLAST CONDITION
PERCENTAGE OF TOTAL 26 IMPACTS
DEFINITIONS IN TABLE FIG 19

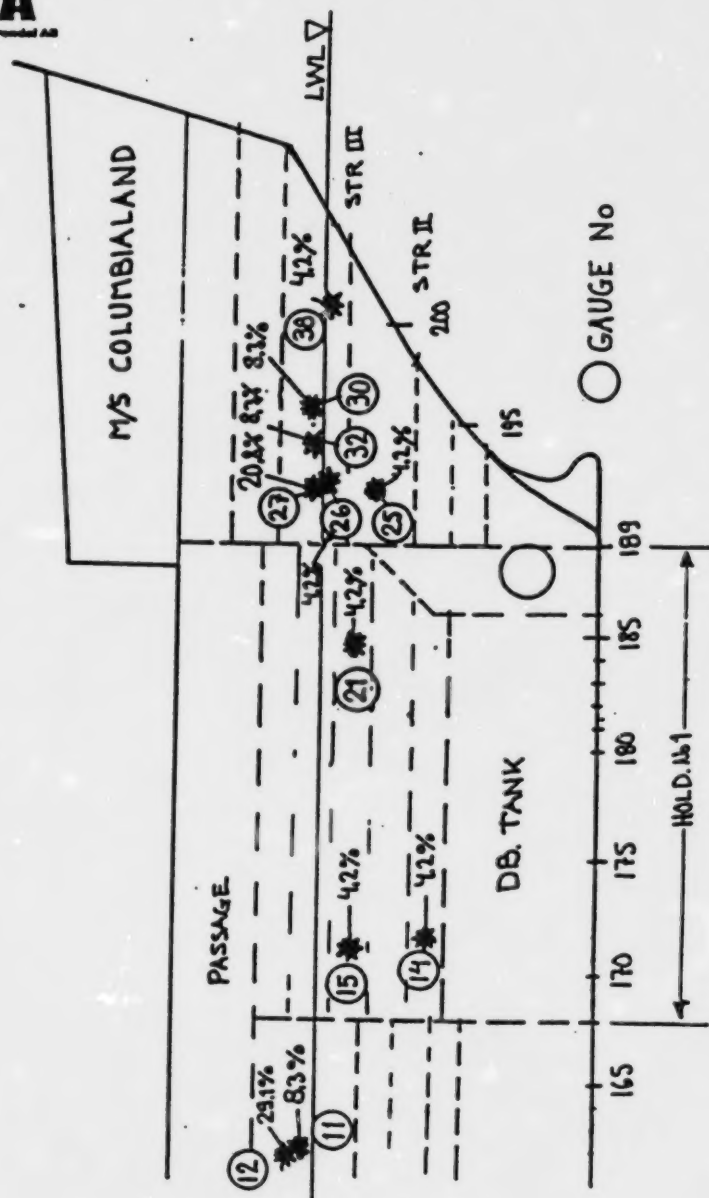


Fig. 14 * IMPACT > 40 MPa LOADED CONDITION
PERCENTAGE OF TOTAL 24 IMPACTS.
DEFINITIONS IN TABLE FIG. 19

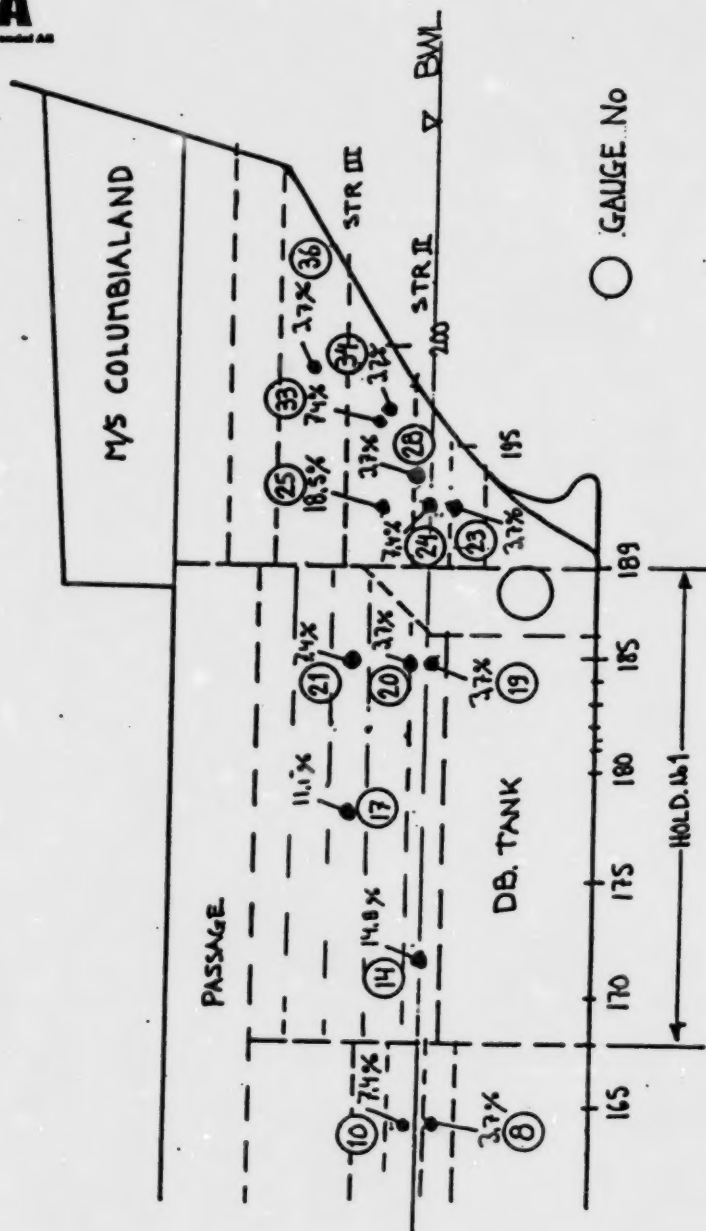


Fig. 15

● IMPACT IN STRESSLEVEL 1, BALLAST CONDITION
PERCENTAGE OF TOTAL 27 IMPACTS.
DEFINITIONS IN TABLE FIG. 20

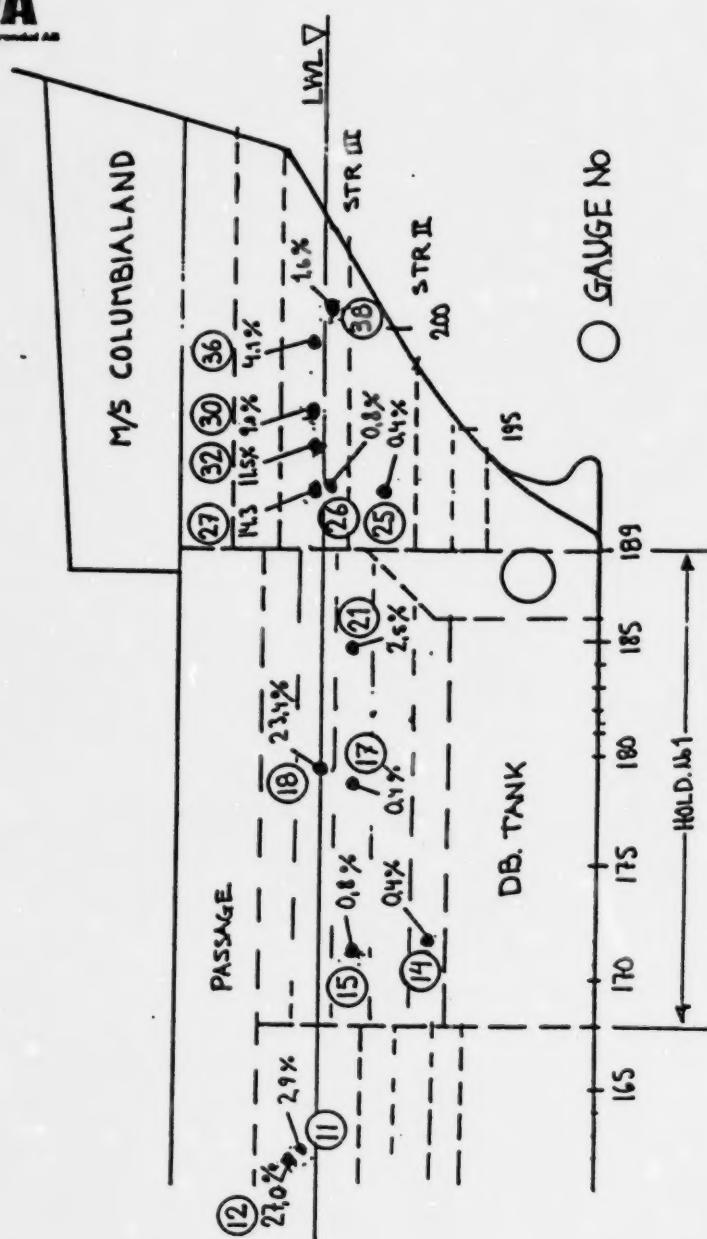


Fig. 16

● IMPACT IN STRESSLEVEL 1 , LOADED CONDITION
PERCENTAGE OF TOTAL 243 IMPACTS.
DEFINITIONS IN TABLE FIG. 20

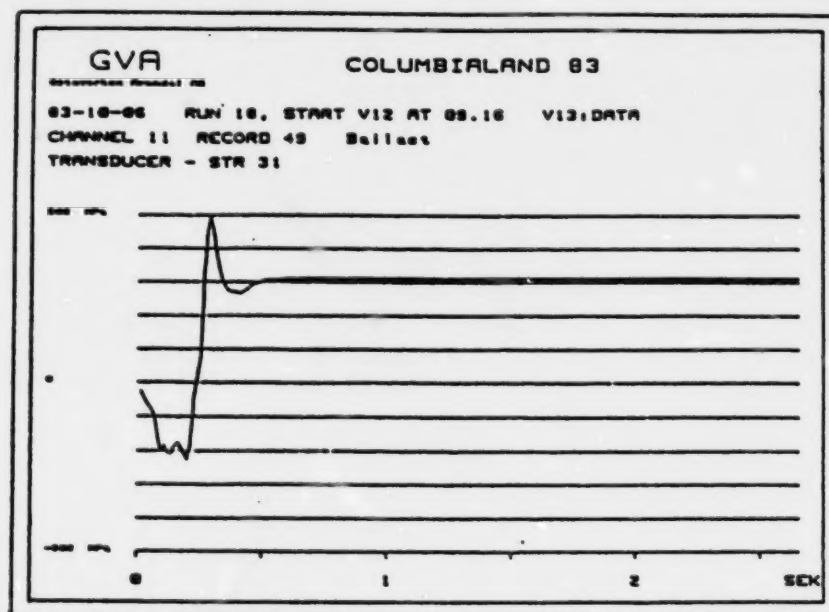


Fig. 17 A MAXIMUM STRESS OF 500 MPa WAS RECORDED AT PLATE GAUGE 31.
FOLLOWING THE IMPACT A PERMANENT STRAIN CORRESPONDING TO
310 MPa WAS RECORDED BY THE SAME GAUGE.
THE YIELD STRESS $\sigma_y = 360$ MPa
SPEED: 5.5 Knots
ICE: SOME LARGER FLOES OF THICKER ICE

GVA
Gibson-Vibration Amplifier

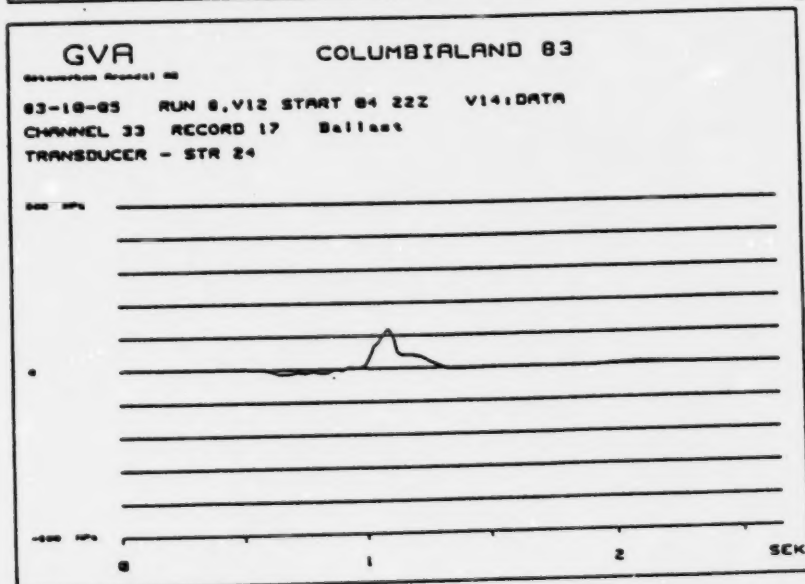
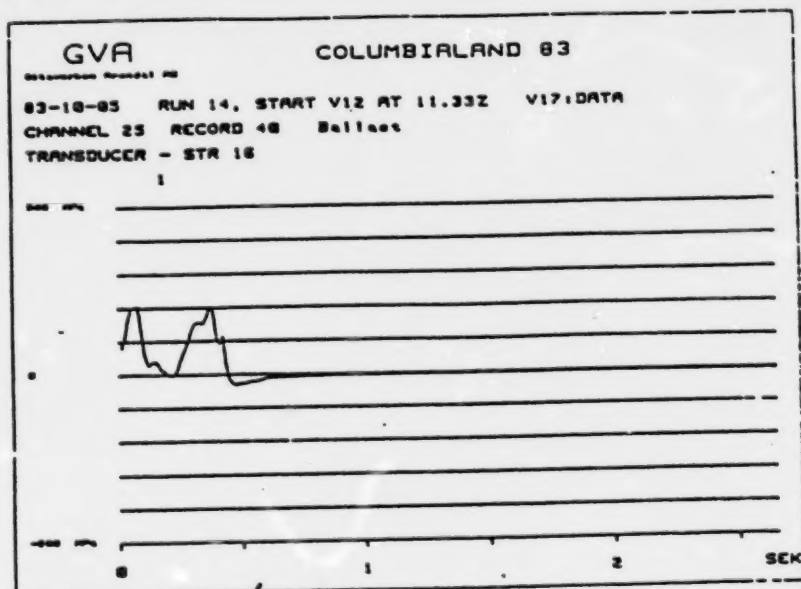


Fig. 18 GAUGES AT PLATES SOMETIMES SHOWS A NEGATIV STRAIN AFTER OR BEFORE THE MAIN IMPACT.

GAUGE No.	BALLAST CONDITION		LOADED CONDITION		GAUGE No.
	number of impacts	%	number of impacts	%	
10	1	3,9			10
11			2	8,3	11
12			7	29,1	12
14	1	3,9	1	4,2	14
15			1	4,2	15
16	3	11,5			16
19	1	3,9			19
21			1	4,2	21
23	7	26,9			23
24	4	15,4			24
25	1	3,9	1	4,2	25
26			1	4,2	26
27			5	20,8	27
28	3	11,5			28
30			2	8,3	30
31	5	19,2			31
32			2	8,3	32
38			1	4,2	38
TOTAL	26	100%	24	100%	

Fig. 19 TABLE OF IMPACTS ≥ 40 MPa.

IMPACTS IN LEVEL +/- 1

GAUGE No	BALLAST CONDITION		LOADED CONDITION	
	number of impacts	%	number of impacts	%
4	-		1	0,4
8	1	3,7	-	
10	2	7,4	0	
11	-		7	2,9
12	-		66	27,2
14	4	14,8	1	0,4
15	0		2	0,8
17	3	11,1	1	0,4
18	-		57	23,5
19	1	3,7	-	
20	1	3,7	0	
21	2	7,4	6	2,4
23	1	3,7	0	
24	2	7,4	-	
25	5	18,5	1	0,4
26	0		2	0,8
27	0		35	14,4
28	1	3,7	0	
30	0		22	9,1
32	-		28	11,5
33	2	7,4	0	
34	1	3,7	0	
36	1	3,7	10	4,1
TOTAL	27	100%	243	100%

NO IMPACTS REGISTERED FROM GAUGE No : 1, 2, 3, 5, 6, 7,
9, 13, 16, 22, 29, 31, 35, 37 AND 38 .

Fig. 20 TABLE OF IMPACTS IN STRESSLEVEL 1 .

GAUGES WITH NO RECORDS OF IMPACTS DURING THE VOYAGE :1, 2, 3, 5, 6,
7, 9, 13, 22, 29, 35, 37.

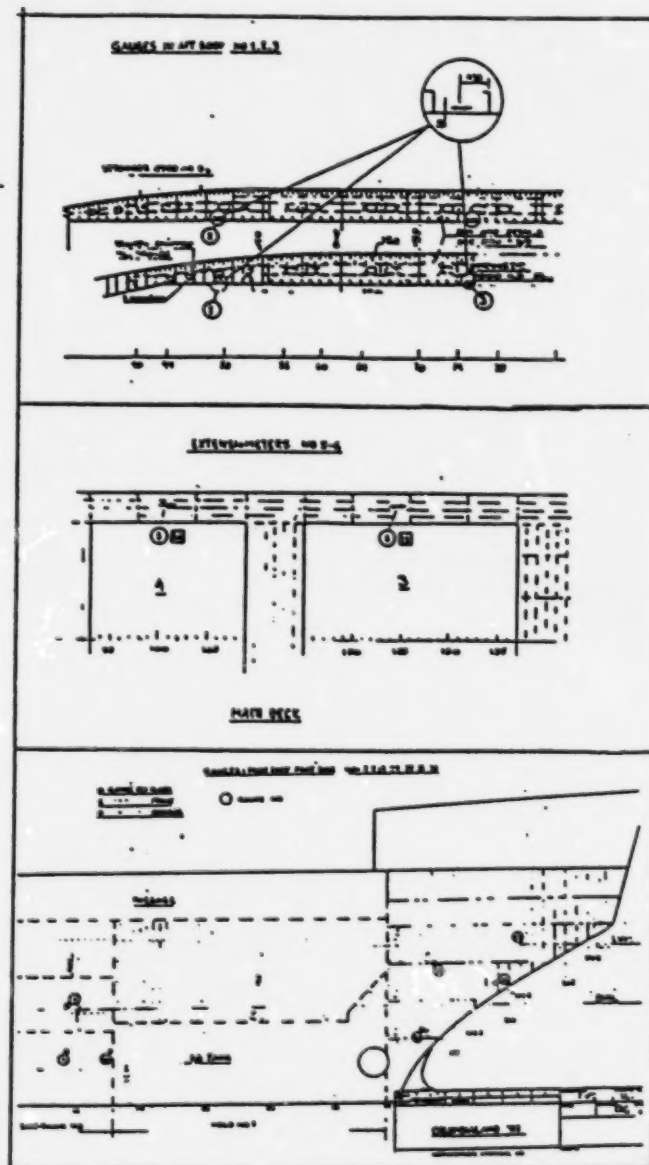


Fig. 21 GAUGES WITH NO RECORDS OF IMPACTS DURING THE VOYAGE.

GVA
Gauges on Plates

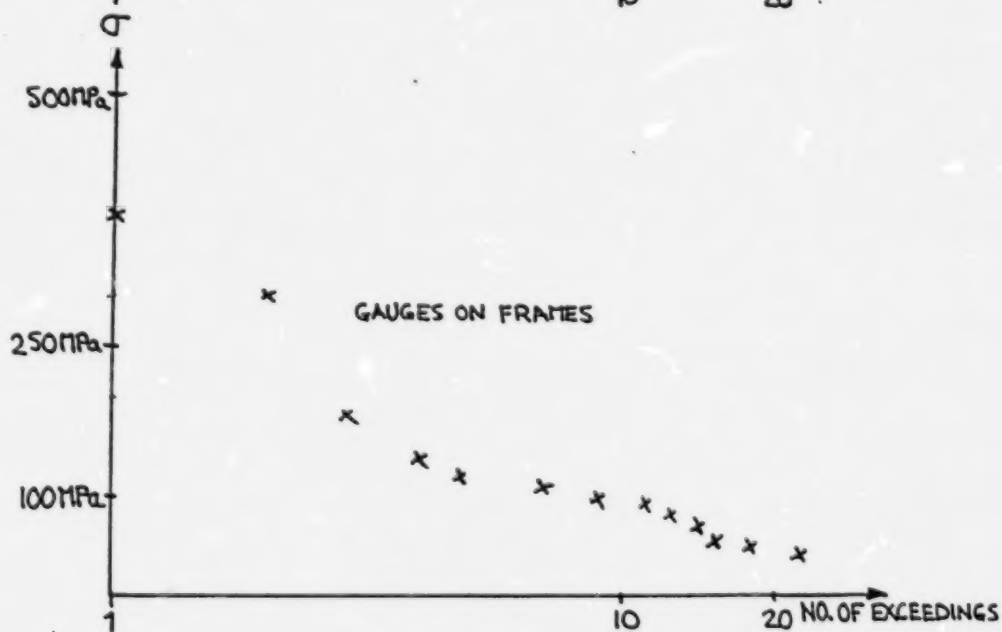
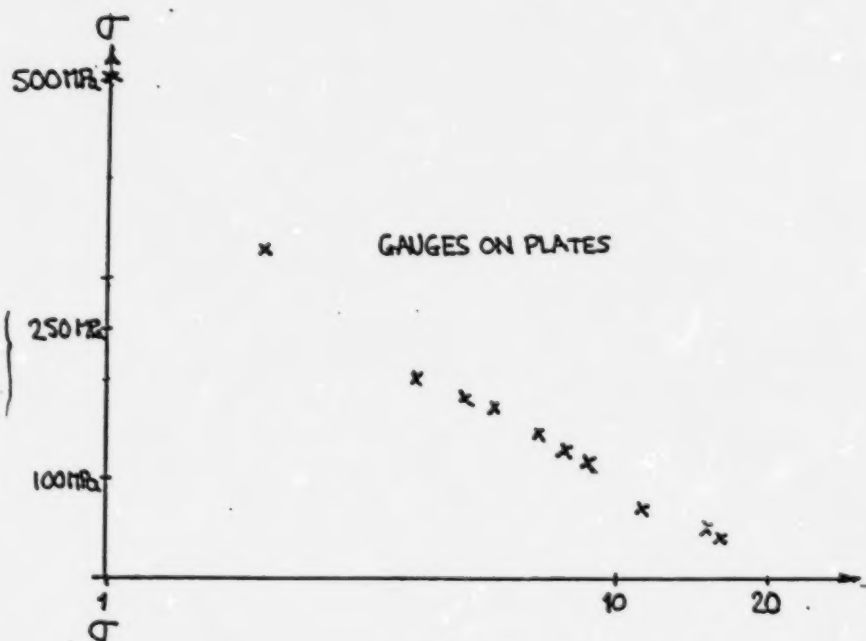


Fig. 22 STRESS LEVEL AS FUNCTION OF NO. OF EXCEEDINGS

GVA
GVA-1000 Series

27

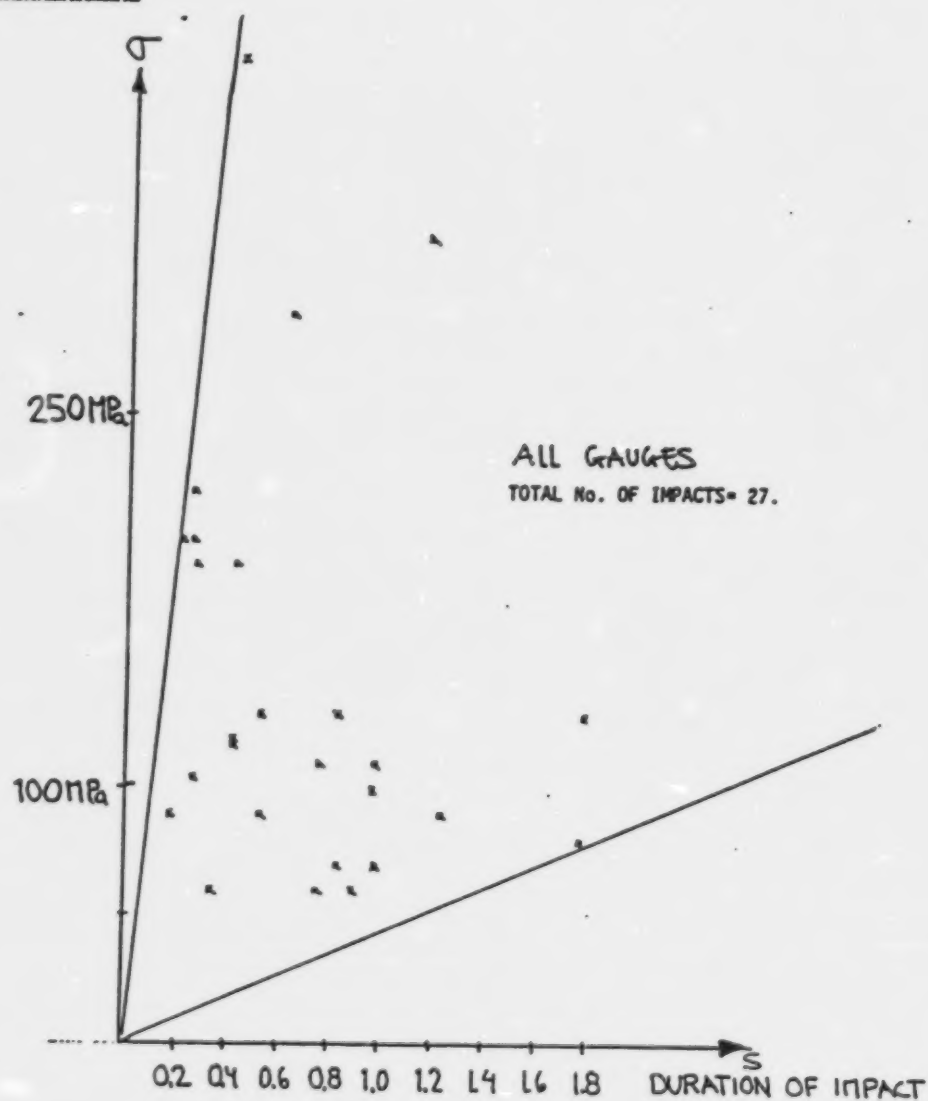


Fig. 23 STRESSLEVEL AS FUNCTION OF THE DURATION OF IMPACT.

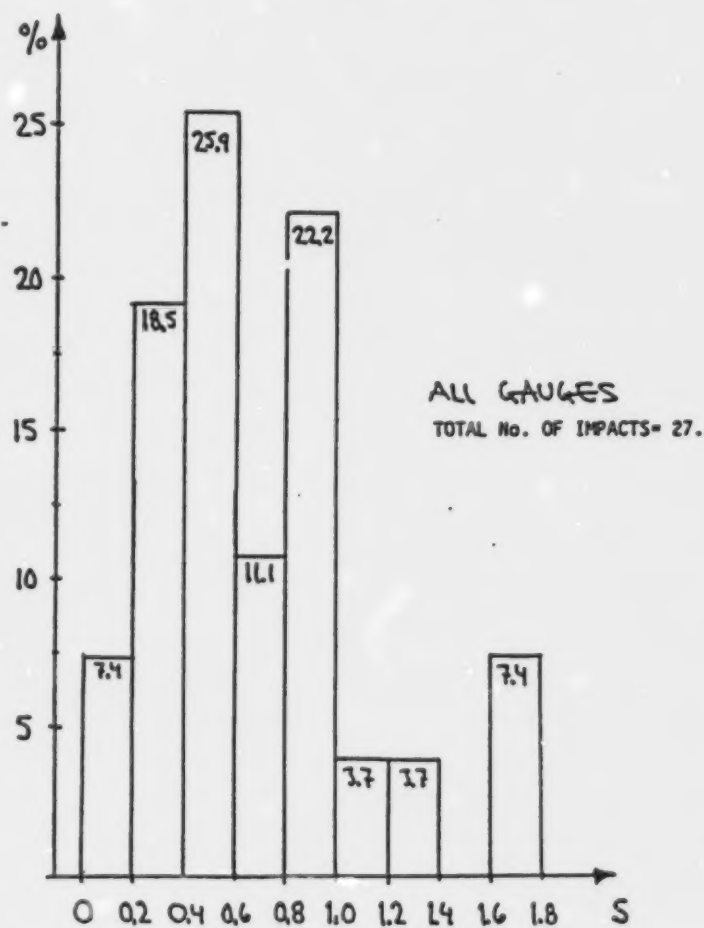
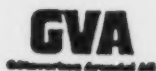


Fig. 24 PERCENTAGE OF TOTAL No. OF IMPACTS AS FUNCTION OF THE DURATION OF IMPACT.



APPENDIX A

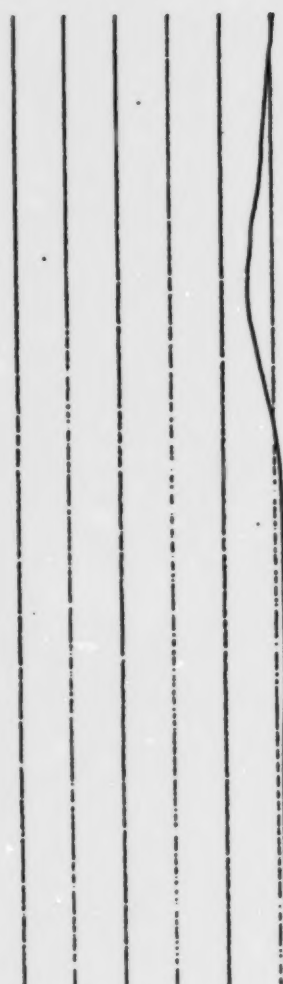
PLOTTED IMPACTS:

	GAUGE No.	Page
ON PLATE	11	A. P:1-2
"	14	:3-4
"	16	:5-6
"	19	:7
"	24	:8-11
"	26	:12
"	31	:13-17
ON FRAME	10	A. F:1
"	12	:2-6
"	15	:7
"	21	:8
"	23	:9-14
"	25	:15-17
"	27	:18-20
"	30	:21-22
"	32	:23-24
ON STRINGER	28	A. S:1-2



GVA COLUMBIALAND 83
 Galsverken Arendal AS
 83-10-13 RUN 56 V12 START AT 14 24Z V16:DATA
 CHANNEL 20 RECORD 23 Loaded
 TRANSDUCER - STR 11

500 MPa



TIME : 14.40

SPEED: 0.6 KNOTS

ICE : 9/10 MY

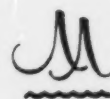
-500 MPa

SEX

0

1

2



GVA

Getuiveren Rendel A3

COLUMBIALAND 83

83-10-13 RUN64 V26 V26:DATA
CHANNEL 20 RECORD 52 Loaded
TRANSDUCER - STR 11

500 MPa



TIME : 19.57

SPEED: 3.0 KNOTS

ICE : 6/10 GREY + 2/10 WHITE

-500 MPa

0 1 2 SEK

A. P:2



GVA : COLUMBIALAND 83
 Gestevoeren Arndel AB
 83-10-05 RUN 14, START V12 AT 11.33Z V17:DATA
 CHANNEL 23 RECORD 40 Ballast
 TRANSDUCER - STR 14

200 MPa

TIME : 11.59

SPEED: 7,2 KNOTS

ICE : NILAS + MY FLOE

-500 MPa

SEK

0

1

2

GVA

Gestevenh Arandel AB

COLUMBIALAND 83

83-10-11 RUN 30 V12 START AT 21 08Z V19:DATA
 CHANNEL 23 RECORD 11 Loaded
 TRANSDUCER - STR 14

800 MPa



TIME : 21.36

SPEED: 9,7 KNOTS

ICE : NILAS

-800 MPa

0 1 2 SEK

GVA		COLUMBIALAND 83	
dataverken Arendal AB			
83-10-05 RUN 14, START V12 AT 11.33Z V17 DATA			
CHANNEL 25 RECORD 40 Ballast			
TRANSDUCER - STR 16			
300 MPa			
			
TIME : 11.59			
SPEED: 7,2 KNOTS			
ICE : NILAS + MY FLOE			
-300 MPa			
0 1 2 SEK			



GVA

Gestevothen Arndal AB

COLUMBIALAND 83

83-10-06 RUN 16, START V18 AT 07.54Z V19:DATA
 CHANNEL 25 RECORD 4 Ballast
 TRANSDUCER - STR 16

200 MPa



-200 MPa

TIME : 08.26

SPEED: 2,7 KNOTS

ICE : SOME HEAVY ICE

SEK

2

1

0

GVA

Gataverken Arrendal AB

COLUMBIALAND 83

83-10-06 RUN 16, START V18 AT 07.54Z V18:DATA
 CHANNEL 28 RECORD 47 Ballast
 TRANSDUCER - STR 19

500 MPa



TIME : 08.24

SPEED: 2,7 KNOTS

ICE : SOME HEAVY ICE IN AREA

-500 MPa

500 MPa

2

1

0

500 MPa

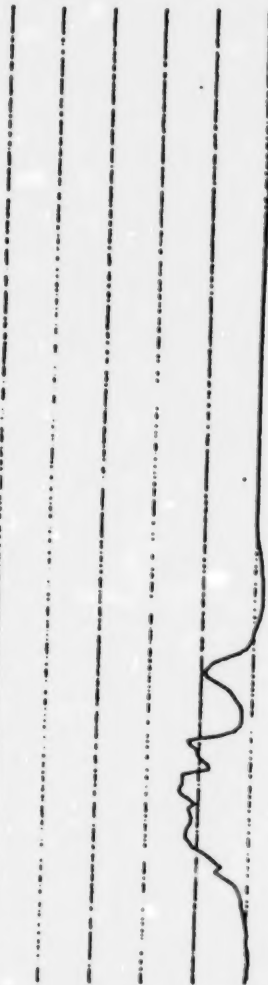
GVA

Geoverken Arendel AB

COLUMBIALAND 83

83-10-05 RUN 8,V12 START 04 22Z V13:DATA
 CHANNEL 33 RECORD 1 Ballast
 TRANSDUCER - STR 24

500 MPa



-500 MPa

TIME : 04.30

SPEED: 1,3 KNOTS

ICE : 7/10 MY

0

1

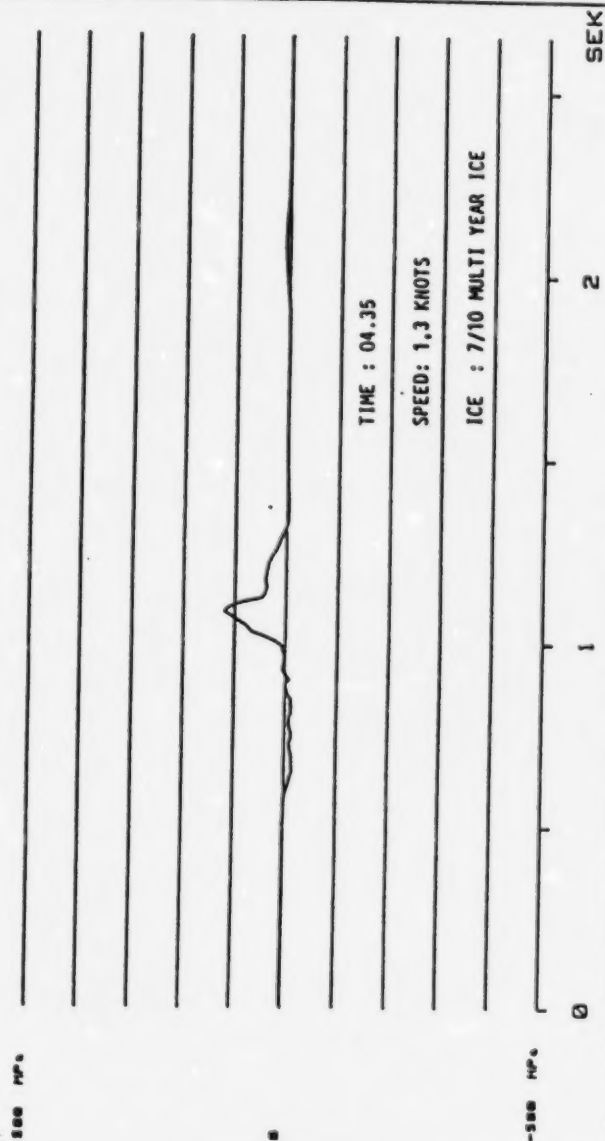
2

SEK

GVA COLUMBIALAND 83

Galsverken Arndal AB

83-10-05 RUN 8,V12 START 04 22Z V14:DATA
 CHANNEL 33 RECORD 17 Ballast
 TRANSDUCER - STR 24



GVA

Gesevorken Rendal AB

COLUMBIALAND 83

83-10-05 RUN 9, START V19 AT 04.53Z V19:DATA
 CHANNEL 33 RECORD 27 Ballast
 TRANSDUCER - STR 24

500 MPa



-500 MPa

TIME : 05.26

SPEED: 0 KNOTS

ICE : 5/10 MULTI YEAR ICE

0

1

2

SEK

GVA COLUMBIALAND 83
 Getaverken Brand -B
 83-10-06 RUN 18, START V12 AT 09.16 V13:DATA
 CHANNEL 33 RECORD 49 Ballast
 TRANSDUCER - STR 24

-500 MPa

TIME : 09.27

SPEED: 5,5 KNOTS

ICE : SOME HEAVY ICE

-500 MPa

0 1 2 SEK

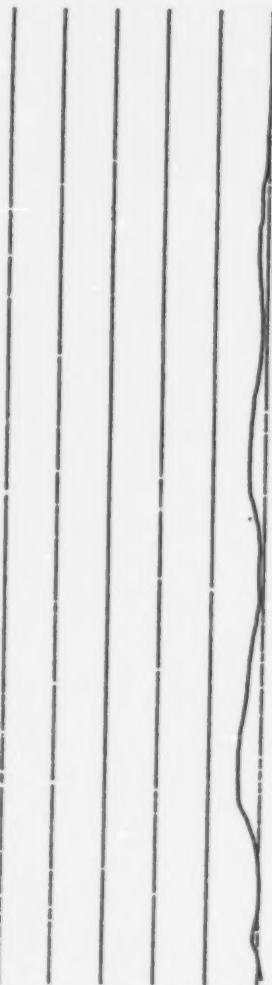
GVA

Gibberken Arendel AB

COLUMBIALAND 83

83-12-13 RUN 56 V12 START AT 14 24Z V20:DATA
 CHANNEL 35 RECORD 6 Loaded
 TRANSDUCER - STR 26

800 MPa



TIME : 15.01

SPEED: 0 KNOTS

ICE : 8/10 MY

-300 MPa

0 1 2 SEK

GVA COLUMBIALAND 83

Gebruiken Arndal AB

83-10-05 RUN 0,V12 START 04 22Z V13:DATA
 CHANNEL 11 RECORD 1 Ballast
 TRANSDUCER - STR 31

500 MPa



TIME : 04.30

SPEED: 1,3 KNOTS

ICE : 7/10 MULTI YEAR ICE

-500 MPa

SEK

2

1

0

GVA

Geoteknisk Arrendal AB

COLUMBIALAND 83

83-10-05 RUN 8,V12 START 04 22Z. V13:DATA
CHANNEL 11 RECORD 2 Ballast
TRANSDUCER - STR 31

800 MPa

-800 MPa

SEK

TIME : 04.30

SPEED: 1,3 KNOTS

ICE : 7/10 MY

2

1

0

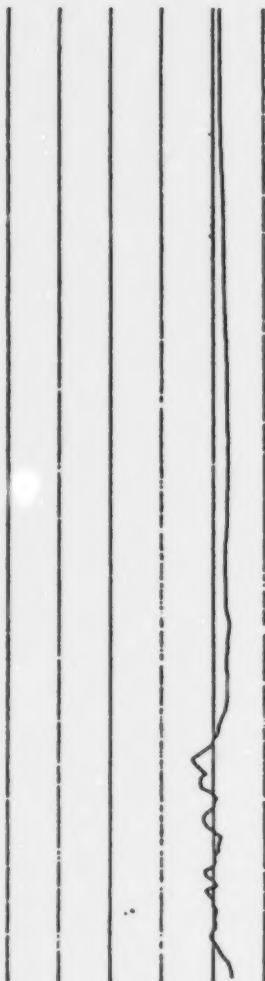


GVA COLUMBIALAND 83'

Date: Verken Arenal 18

83-10-05 RUN 8,V12 START 04 22Z V18:DATA
CHANNEL 11 RECORD 22 Ballast
TRANSDUCER - STR 31

SEE MP's

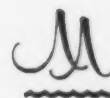


TIME : 04.51

SPEED: 1,3 KNOTS

ICE : 7/10 MY

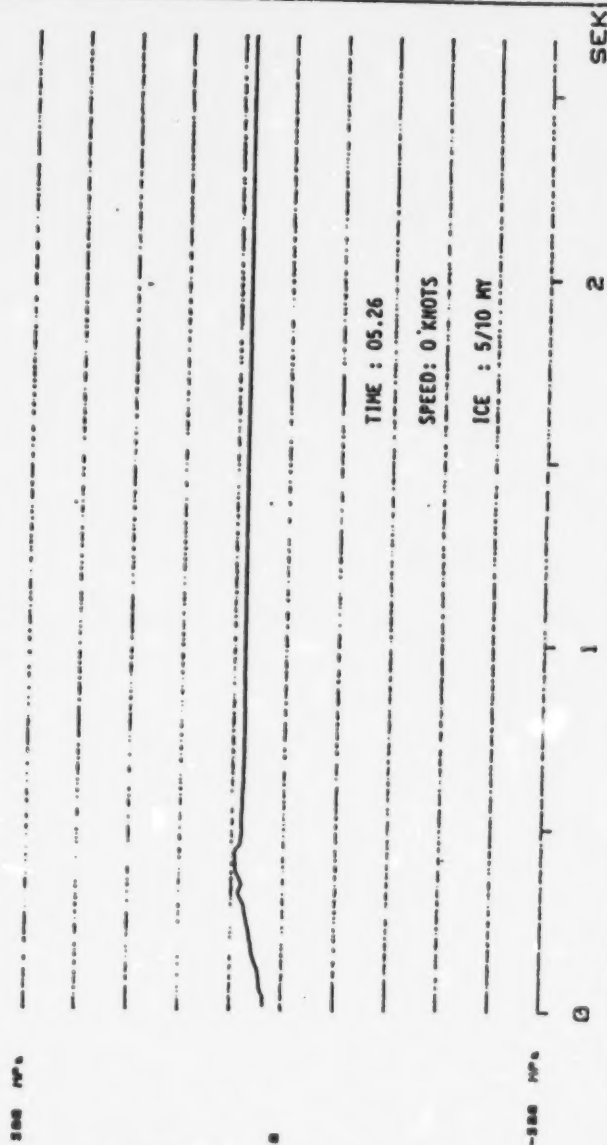
SEE MP's



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Galsverken Arndal AB

COLUMBIALAND 83

03-10-05 RUN 9, START V19 AT 04.53Z V19:DATA
CHANNEL 11 RECORD 27 Ballast
TRANSDUCER - STR 31



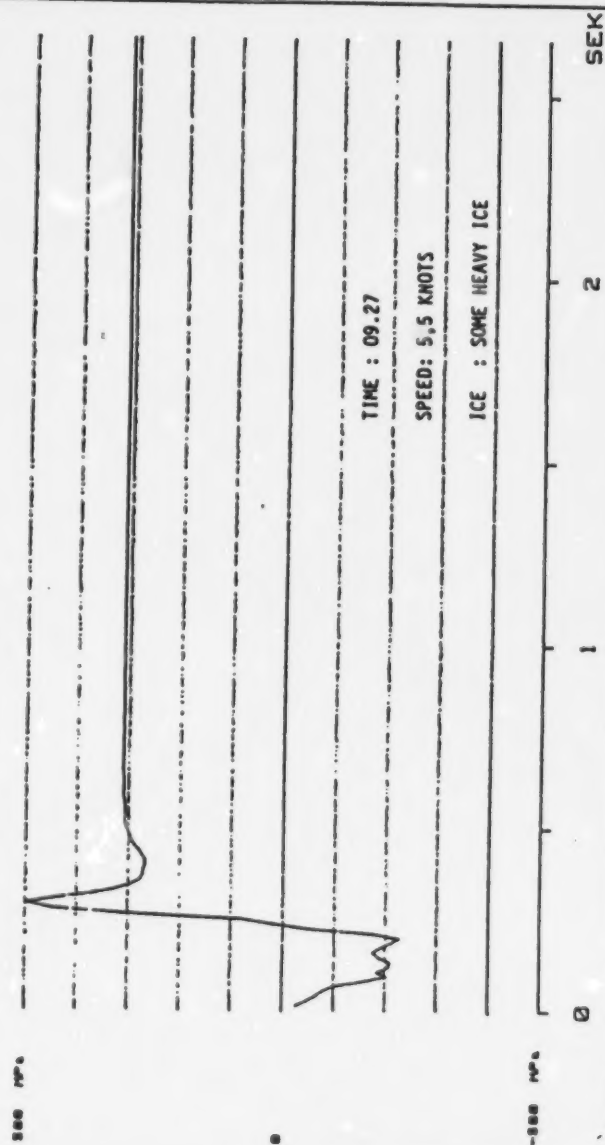
GVA
Geoteknisch Afdeling AB

COLUMBIALAND 83

83-10-06 RUN 10, START V12 AT 09.16 V13:DATA

CHANNEL 11 RECORD 49 Ballast

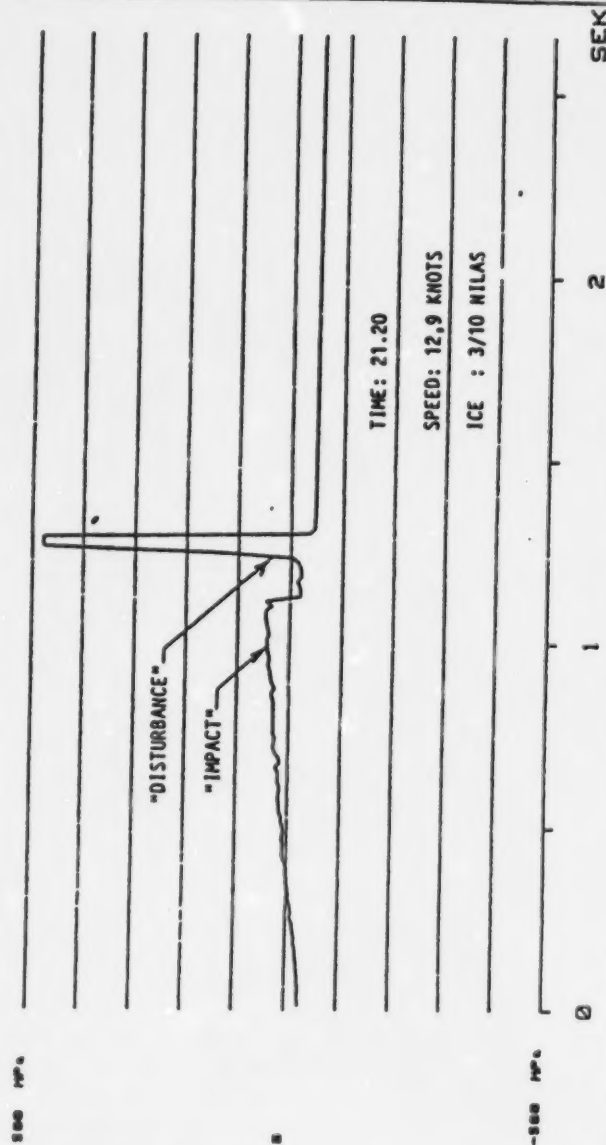
TRANSDUCER - STR 31



GVA
 Dataverken Arndal AB

COLUMBIALAND 83

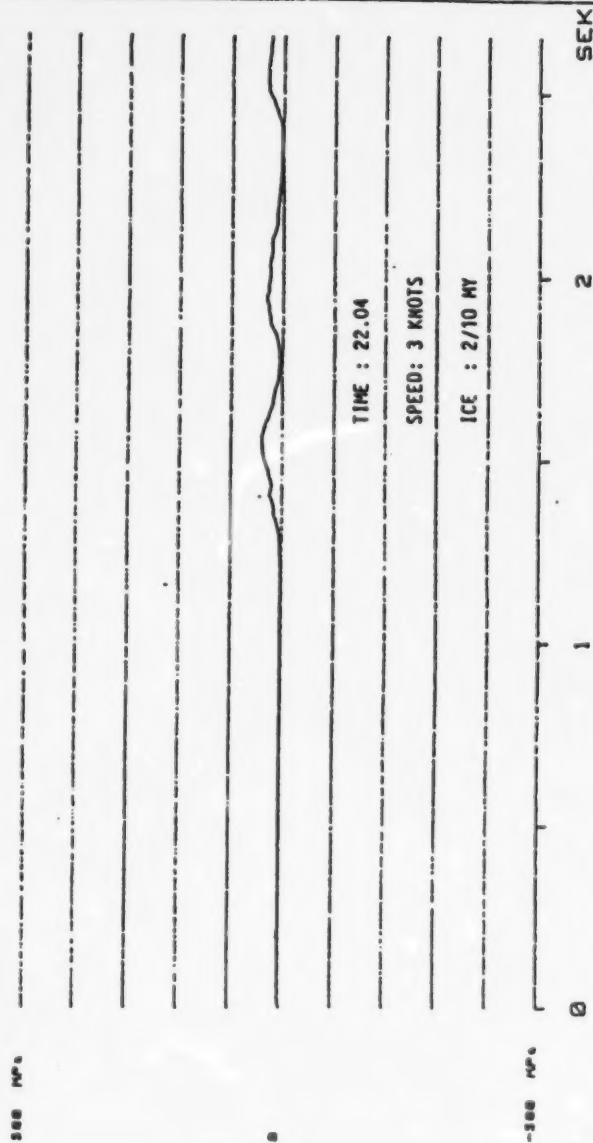
83-10-04 RUN 3 START AT V21, 20.19Z V26:DATA
 CHANNEL 19 RECORD 23 Ballast
 TRANSDUCER - STR 10



A. F:1



GVA COLUMBIALAND 83
 83-10-11 RUN 30 V12 START AT 21 00Z V26:DATA
 CHANNEL 21 RECORD 11 Loaded
 TRANSDUCER - STR 12



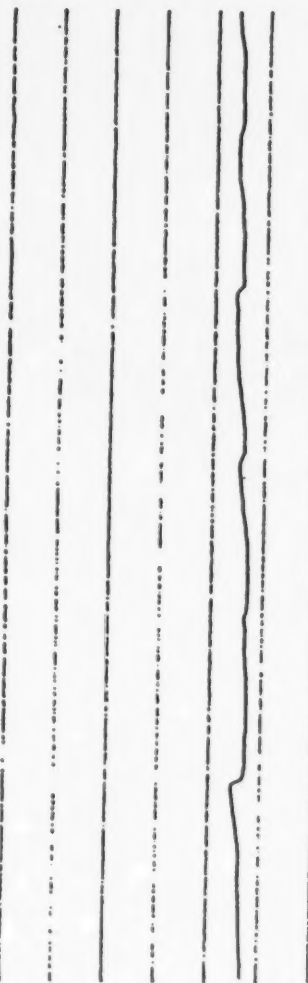
GVA

Gestecken Arndal AB

COLUMBIALAND 83

83-10.13 RUN 54 V20 START AT 13 36Z V20:DATA
 CHANNEL 21 RECORD 54 Loaded
 TRANSDUCER - STR 12

300 MPa



-300 MPa

0

1

2

SEC

TIME : 14.15

SPEED: 0 KNOTS

ICE : 10/10 MY

GVA

Gstaaviken Rendal AB

COLUMBIALAND 83

83-10.13 RUN 54 V20 START AT 13 36Z V20:DATA
 CHANNEL 21 RECORD 55 Loaded
 TRANSDUCER - STR 12

880 MPa

TIME : 14.15

SPEED: 0 KNOTS

ICE : 10/10 MY

-300 MPa

0

1

2

SEK



GVA
Gefuervken Arendel AB

COLUMBIALAND 83

83-10.13 RUN 54 V20 START AT 13 36Z V20:DATA
CHANNEL 21 RECORD 56 Loaded
TRANSDUCER - STR 12

500 MPa

TIME : 14.15
SPEED: 0 KNOTS
ICE : 10/10 MY

0 1 2

SEK



GVA

Getaverken Arendal AS

COLUMBIALAND 83

83-10.13 RUN 54 V20 START AT 13 36Z V20:DATA

CHANNEL 21 RECORD 57 Loaded

TRANSDUCER - STR 12

-500 MPa

TIME : 14.15

SPEED: 0 KNOTS

ICE : 10/10 MY

-500 MPa

0

1

2

SEK

A. F:6



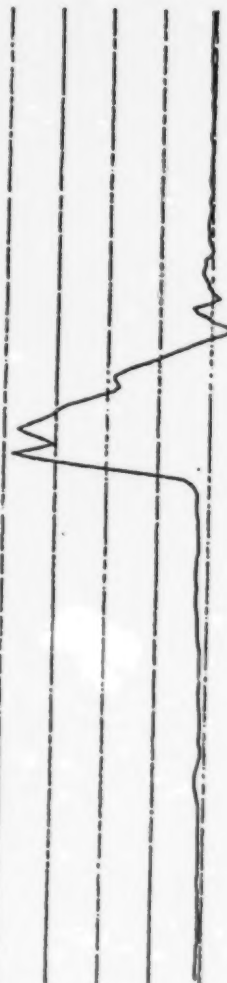
A. F:7

GVA
Gesteueren Arndel AB

COLUMBIALAND 83

83-10-11 RUN 30 V12 START AT 21 08Z V19:DATA
CHANNEL 24 RECORD 11 Loaded
TRANSDUCER - STR 15

500 MPa



TIME : 21.36

SPEED: 9,7 KNOTS

ICE : NILAS

-300 MPa

0 1 2 SEK

GVA COLUMBIALAND 83

Gataverken Arendal AB

83-10-11 RUN 26, V12, START AT 0939Z V12:DATA
CHANNEL 30 RECORD 52 Loaded
TRANSDUCER - STR 21

500 MPa

TIME : 09.43

SPEED: 1,8 KNOTS

ICE : 7/10 GREY ,BEST MY

-500 MPa

SEK

2

0

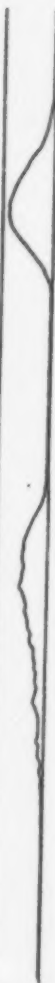
GVA

Geoteknisch Bureau

COLUMBIALAND 83

83-10-05 RUN 8, V12 START 04 22Z V14: DATA
CHANNEL 32 RECORD 17 Ballast
TRANSDUCER - STR 23

300 MPa



-300 MPa

TIME : 04.35

SPEED: 1,3 KNOTS

ICE : 7/10 MULTI YEAR ICE

SEK

2

0

A. F:10

GVA

Gebruiken Brandel AB

COLUMBIALAND 83

83-10-05 RUN 8,V12 START 04 22Z V10:DATA
CHANNEL 32 RECORD 22 Ballast
TRANSDUCER - STR 23

300 MPa



TIME : 04.51

SPEED: 1,3 KNOTS

ICE : 7/10 MY

-300 MPa

SEK



GVA

Getaverden Rindal AB

COLUMBIALAND 83

83-10-05 RUN 11, START V12 AT 06.45Z V18:DATA
CHANNEL 32 RECORD 59 Ballast
TRANSDUCER - STR 23

SEE MP



TIME : 07.16

SPEED: 1.5 KNOTS

ICE : 4/10 MY

SEE MP

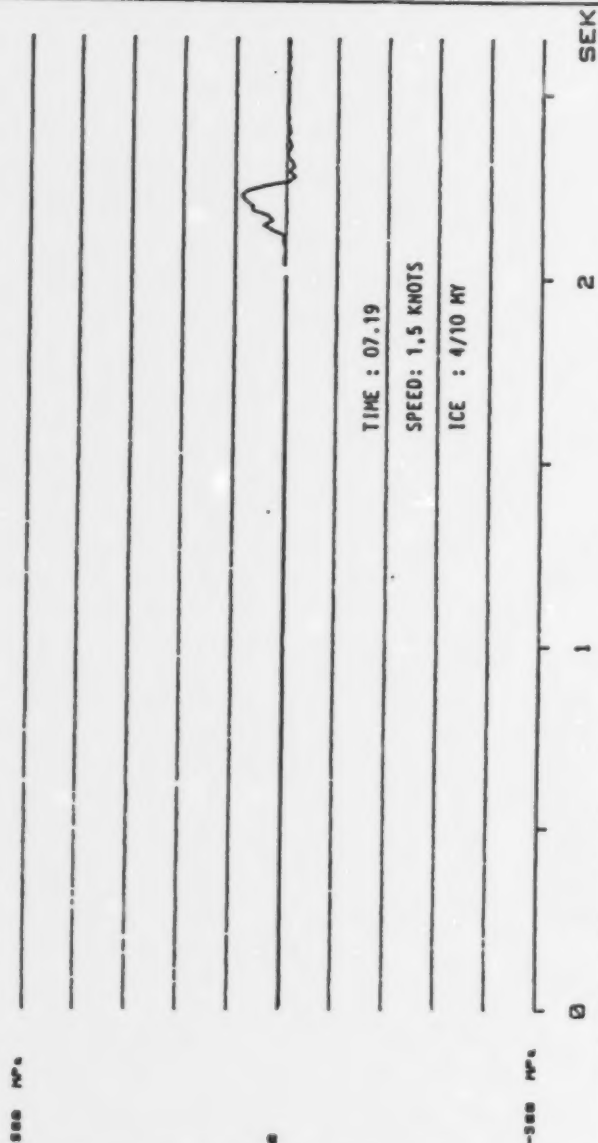
0 1 2 SEK



GVA
Gestevenen Arendel AB

COLUMBIALAND 83

83-10-05 RUN 11, START V12 AT 06.45Z V19:DATA
CHANNEL 32 RECORD 36 Ballast
TRANSDUCER - STR 23



GVA

Gestevothen Arendal AB

COLUMBIALAND 83

83-10-06 RUN 16, START V18 AT 07.54Z V19:DATA
 CHANNEL 32 RECORD 10 Ballast
 TRANSDUCER -- STR 23

300 MPa



-300 MPa

0

1

2

SEK

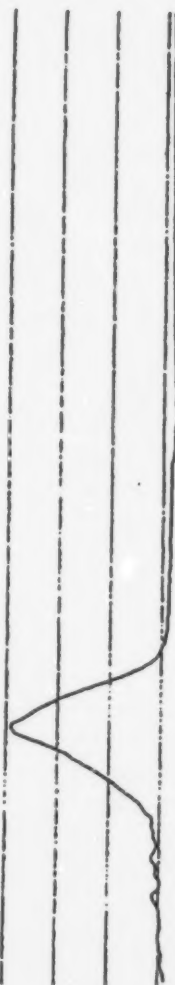
TIME : 08.27

SPEED: 2,7 KNOTS

ICE : SOME HEAVY ICE

GVA
 Gatoverken Arendal AB
 COLUMBIÅLAND 83
 83-10-06 RUN 18, START V12 AT 09.16 V13:DATA
 CHANNEL 32 RECORD 49 Ballast
 TRANSDUCER - STR 23

500 MPa



-300 MPa

TIME : 09.27

SPEED: 5,5 KNOTS

ICE : SOME HEAVY ICE

0

1

2

SEK

GVA

Gelassenen Brandel AB

COLUMBIALAND 83

83-10-05 RUN 9, START V19 AT 04.53Z V19:DATA
CHANNEL 34 RECORD 27 Ballast
TRANSDUCER - STR 25

500 MPa



TIME : 05.26

SPEED: 0 KNOTS

ICE : 5/10 MULTI YEAR ICE

-500 MPa



M

GVA

Goteviken Arndal AB

COLUMBIALAND 83

83-10-06 RUN 18, START V12 AT 09.16 V13:DATA
 CHANNEL 34 RECORD 49 Ballast
 REBNSØCER - STR 25

500 MPa

TIME : 09.27

SPEED: 5.5 KNOTS

ICE : SOME HEAVY ICE

-500 MPa

SEK

2

1

0

GVP

Geophysical Research AB

COLUMBIALAND 83

83-10-13 RUN: 56 V12 START AT 14 24Z V14: DATA
 CHANNEL 34 RECORD 21 Loaded
 TRANSDUCER - STR 25

300 MPa

-300 MPa

TIME : 14.35

SPEED: 0.6 KNOTS

ICE : 9/10 MY

SEK

2

1

0



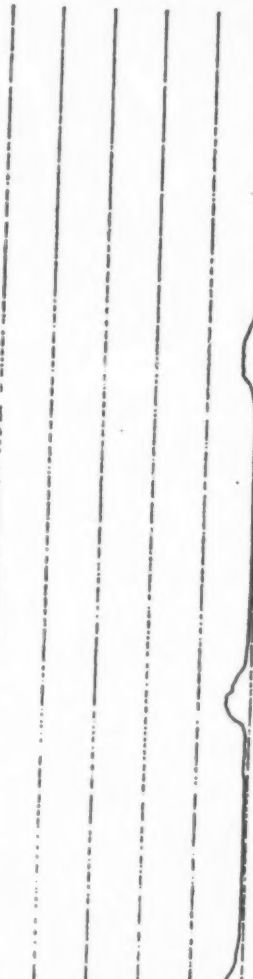
GVA

Gestevoeken Arendal AS

COLUMBIALAND 83

83-10-11 RUN 30 V12 START AT 21 00Z V24:DATA
 CHANNEL 36 RECORD 58 Loaded
 TRANSDUCER - STR 27

500 MPa



TIME : 21.59

SPEED: 3 KNOTS

ICE : 2/10 MY

-500 MPa

0

1

2

SEC

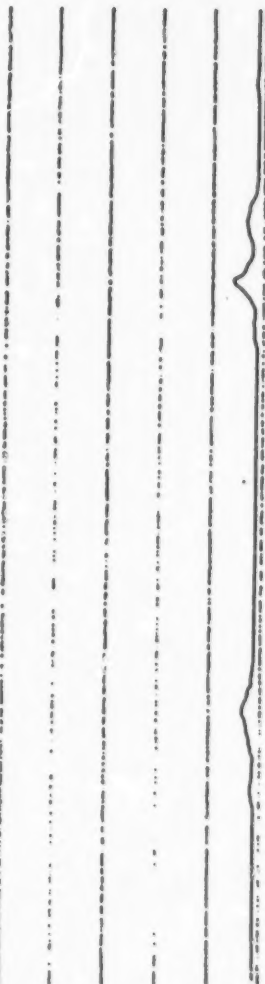
GVA

Gebruiken Aranda AB

COLUMBIALAND 83

83-10-13 RUN 66 V13 START AT 18 32Z V13:DATA
CHANNEL 36 RECORD 6 Loaded
TRANSDUCER - STR 27

800 MPa



TIME : 18.40

SPEED: 3.6 KNOTS

ICE : 6/10 NILAS + 3/10 GREY + 1/10 WHITE

-300 MPa



SEK

A. F:19

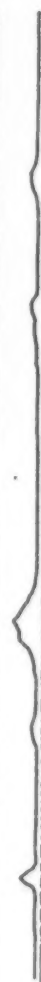
GVA

Gesteven Arandel AB

COLUMBIALAND 83

83-10-13 RUN 67 V14 START AT 18 39Z V14:DATA
 CHANNEL 36 RECORD 4 Loaded
 TRANSDUCER - STR 27

300 MPa



TIME : 18.40

SPEED: 4,5 KNOTS

ICE : 6/10 OPEN WATER + NILAS, BEST GREY AND WHITE

-350 MPa

SEK

0

1

2

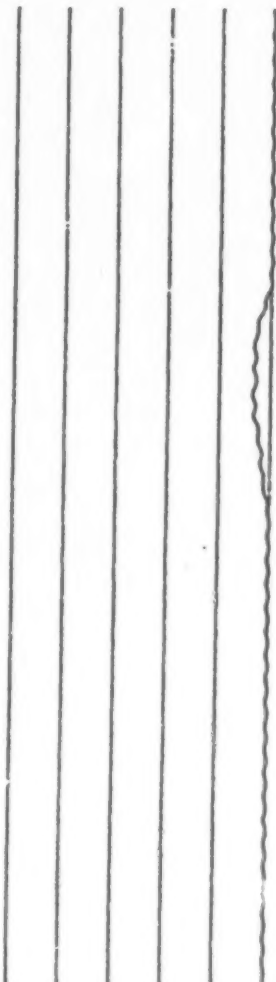
GVA

Gossvorben Arendal AS

COLUMBIALAND 83

83-10-12 RUN49 V13, START AT 2334Z VIS:DATA
 CHANNEL 39 RECORD 11 Loaded
 TRANSDUCER - STR 30

500 MPa



TIME : 23.50

SPEED: 3,6 KNOTS

ICE : CLOSE PACKICE EDGE+BIG PIECES MY

-500 MPa



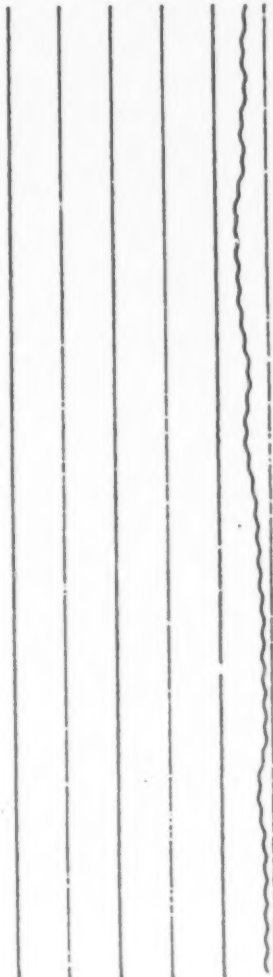
GVA

Geleverden Arndel AB

COLUMBIALAND 83

83-10-13 RUN 56 V12 START AT 14 24Z V19:DATA
CHANNEL 39 RECORD 64 Loaded
TRANSDUCER - STR 30

200 MPa



TIME : 15.00

SPEED: 0 KNOTS

ICE : 8/10 MY

200 MPa



GVA

Geslovenen Rendal AB

COLUMBIALAND B3

83-10-12 RUN49 V13, START AT 2334Z V15:DATA
CHANNEL 12 RECORD 11 Loaded
TRANSDUCER - STR 32

500 MPa



-500 MPa

0

1

2

SEK

TIME : 23.50

SPEED: 3.6 KNOTS

ICE : CLOSE PACKICE EDGE+BIG PIECES MY

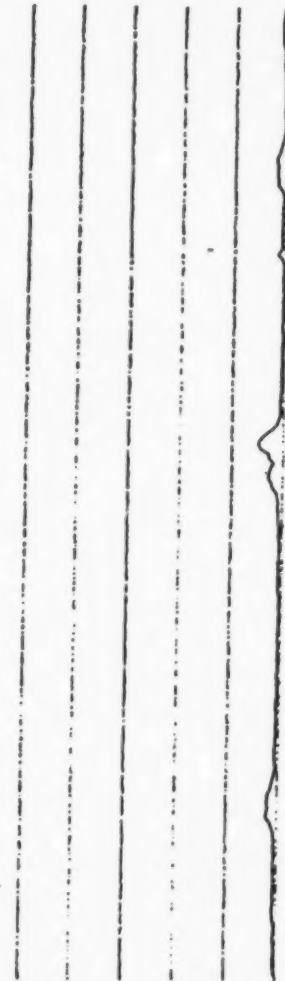


GVA

Geleverden Arendal AB

COLUMBIALAND 83

83-10-13 RUN 68 V15 START AT 18 46Z V17:DATA
 CHANNEL 12 RECORD 60 Loaded
 TRANSDUCER - ST.



TIME : 19.02

SPEED: 4,5 KNOTS

 ICE : 6/10 OPEN WATER-NILAS-REST GREY
 AND-WHITE

-500 MPa

0

1

2

SEK

A. S:1

GVA

Geoteknisch Bureau

COLUMBIALAND 83

83-10-05 RUN 9, START V19 AT 04.53Z V19:DATA
CHANNEL 37 RECORD 27 Ballast
TRANSDUCER - STR 28

500 MPa



-500 MPa

TIME : 05.26

SPEED: 0 KNOTS

ICE : 5/10 MY

SEK

2

0



GVA

Geoteknisk Aarsdal AS

COLUMBIALAND 83

83-10-06 RUN 18, START V12 AT 09.16 V13:DATA
CHANNEL 37 RECORD 49 Ballast
TRANSDUCER - STR 28

500 MPa



TIME : 09.27

SPEED: 5.5 KNOTS

ICE : SOME HEAVY ICE

-500 MPa



SEC

APPENDIX B

EXPLANATIONS TO PRINTOUTS

Page: B.1-2

EXAMPLE OF PRINTOUTS

B.3-5



EXPLANATION TO PRINTOUTS

THE TABLE STARTS IN VOLUME 12 , CONTAINING 9 VOLUMES (12 - 20).

-T = THE SIGNAL IS FILTERED

DATE OF ANALYS

RUN 14 STARTS IN VOLUME 12 AT 11.33

DATE OF MEASUREMENT

[83-10-05]		RUN 14, [START V12 AT 11.33] / [-T M 84 5 8]		[9 VOL V12]											
SIGNL	N+1	N+2	N+3	N+4	N+5	N+6	N+7	N+8	N+9	N+10	N+11	N+12	N+13	N+14	N+15
MVD	N-1	N-2	N-3	N-4	N-5	N-6	N-7	N-8	N-9	N-10	N-11	N-12	N-13	N-14	N-15
# 25	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
# 26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
# 27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
# 28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Which channel to start the table ? (1,5,9,13,17,21,25,29,33 or 37, 0=Return)

Explanation to printouts

SIGN		N + 2	
MVD		N - 2	ETC
C			
D			
2		0	
4		1	
		0	
		307	
		0	
		13	
ETC			

- A Level No 1 positive
 B Level No 1 negative
 C Channel No
 D Meanvalue
 E Number of crossings of first positive level on channel 1, (=3) if the number exceeds 9999 the next digit will be in the topline; see also G.
 F Number of crossing of first negative level on channel 1. (=1)
 G Number of crossing of first level on channel two = 13752
 (Note: Highest number of crossing is 99999999)

3-10-05 RUN 8,V12 START 04 22Z / -T (84 5 4) 7 VOL V12

IGNL	N+1	N+2	N+3	N+4	N+5	N+6	N+7	N+8	N+9	N+10	N+11	N+12	N+13	N+14	N+15
VD	N-1	N-2	N-3	N-4	N-5	N-6	N-7	N-8	N-9	N-10	N-11	N-12	N-13	N-14	N-15
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ich channel to start the table ? (1,5,9,13,17,21,25,29,33 or 37, 0=Return)

-10-05 RUN 8,V12 START 04 22Z / -T (84 5 4) 7 VOL V12

IGNL	N+1	N+2	N+3	N+4	N+5	N+6	N+7	N+8	N+9	N+10	N+11	N+12	N+13	N+14	N+15
VD	N-1	N-2	N-3	N-4	N-5	N-6	N-7	N-8	N-9	N-10	N-11	N-12	N-13	N-14	N-15
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ich channel to start the table ? (1,5,9,13,17,21,25,29,33 or 37, 0=Return)

1-10-05 RUN 14, START V12 AT 11.33Z / -T (84 5 8) 9 VOL V12

(GNL	N+1	N+2	N+3	N+4	N+5	N+6	N+7	N+8	N+9	N+10	N+11	N+12	N+13	N+14	N+15
IVD	N-1	N-2	N-3	N-4	N-5	N-6	N-7	N-8	N-9	N-10	N-11	N-12	N-13	N-14	N-15
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-1	1	1	2	1	1	2	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

rich channel to start the table ? (1,5,9,13,17,21,25,29,33 or 37, 0=Return)

3-10-05 RUN 14, START V12 AT 11.33Z / -T (84 5 8) 9 VOL V12

(GNL	N+1	N+2	N+3	N+4	N+5	N+6	N+7	N+8	N+9	N+10	N+11	N+12	N+13	N+14	N+15
IVD	N-1	N-2	N-3	N-4	N-5	N-6	N-7	N-8	N-9	N-10	N-11	N-12	N-13	N-14	N-15
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

rich channel to start the table ? (1,5,9,13,17,21,25,29,33 or 37, 0=Return)

3-10-06 RUN 18, START V12 AT 09.16 / -T (84 5 8) 15 VOL V12

IGNL	N+1	N+2	N+3	N+4	N+5	N+6	N+7	N+8	N+9	N+10	N+11	N+12	N+13	N+14	N+15
V12	N-1	N-2	N-3	N-4	N-5	N-6	N-7	N-8	N-9	N-10	N-11	N-12	N-13	N-14	N-15
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

hic. channel to start the table ? (1,5,9,13,17,21,25,29,33 or 37, 0-Return)

3-10-06 RUN 18, START V12 AT 09.16 / -T (84 5 8) 15 VOL V12

IGNL	N+1	N+2	N+3	N+4	N+5	N+6	N+7	N+8	N+9	N+10	N+11	N+12	N+13	N+14	N+15
V12	N-1	N-2	N-3	N-4	N-5	N-6	N-7	N-8	N-9	N-10	N-11	N-12	N-13	N-14	N-15
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

hic. to start the table ? (1,5,9,13,17,21,25,29,33 or 37, 0-Return)



APPENDIX B
INFORMATION ON MS COLUMBIALAND





Dimensions and Particulars

Length over all	185.822 m = 609' 7 ³ / ₄ "
Length between p.p.	176.980 m = 580' 7 ³ / ₄ "
Breadth moulded	26.500 m = 86' 11 ¹ / ₄ "
Breadth extreme	26.550 m = 87' 1 ¹ / ₄ "
Depth moulded to upper deck	15.500 m = 50' 10 ¹ / ₄ "
Height of foremast above keel	abt. 36 m
Height of radarmast above keel	abt. 46.5 m
Distance from bridge to bow	abt. 156 m
Distance from bridge to stern	abt. 30 m
Number of holds	6

Length × breadth of holds:

No 1 on tank top length 15.40 (50' 6¹/₄") × breadth aft 17.4 m (57' 1¹/₄")
forw. 6.50 m (21' 4")

No 2, 3, 5 23.20 m × 21.00 m (76' 1¹/₄" × 68' 11")

No 4 18.00 m × 21.00 m (59' 3¹/₄" × 68' 11")

No 6 23.40 m × 21.00 m (76' 9¹/₄" × 68' 11"), breadth on tank top
aft 13 m (42' 7¹/₄")

Dimensions of hatches, length × breadth:

No 1 12.90 × 15.60 m = 42' 4" × 51' 2"

No 2, 3, 5, 6 18.92 × 21.00 m = 62' 1" × 68' 11"

No 4 13.76 × 21.00 m = 45' 2" × 68' 11"

Hatch coaming, height 1950 mm.

Height between tanktop and bottom of hatch cover 15.60 m = 51' 2"
Hatch covers of Navire's folding type, hydraulic operated and of box
type design. Reinforcement for two layers of 20 or 40' containers.

Hydraulic aggregate for hatches placed under forecabin, type Chevron
Aviation, Sperry Vickers, motors type HXUR/C 408G2 V1, 40 kW, 1765
RPM. Maker: Oy Strömberg, Finland.

Emergency power unit for hatch covers, portable type No A 6027, made
by Sperry Vickers. Motor type HXUR/C 325 G3 B3/85, 9 kW, 1150 RPM.
Maker: Oy Strömberg.

5 electro-hydraulic cargo cranes, three single and two twin type, SWL
25 tonnes, working radius 26 m, hoisting speed at full load 26 m/min.
Maker of cranes: ASEA/Hägglund.

2 provisions cranes, type SVCSP, cap 5 ton. Maker: Wärtsilä, Kotka.

1 provision crane, type 1500/1650, cap 1.5 ton. Maker: Sigval Bergesen
Mek. Verksted, Sandnes, Norway. Air driven winch motor, type
Pentair 750. Maker: SAMITA.

2 electro-hydraulic windlasses, combined with mooring winches. Wind-
lasses type AMF 63/68-66 K3, winches type MF 160, hydr. motor
type M-204.

4 el. hydraulic mooring winches, type MF 120, 12 tons pull. Motor
type M 140 V. 3 winches placed aft and 1 on forecabin.

Hydraulic pump plant for mooring winches and windlasses, aft and
forward, each comprising.

3 main pumps, type SV 12 A. Motors type QFV 200 M4C, 77 kW,
1735 RPM. Maker: NEBB.

3 mooring pumps, type SNF 210 R 46 S, cap 390 lit/min. Maker: All-
weiler AG. Motors type QF 160 M4C, 15.5 kW, 1750 RPM. Maker:
NEBB.

Maker of mooring equipment and main pumps: Norwinch Group, Bergen,
Norway.

Loadmax calculator type LM 100 placed in decks office. Maker: Ray-
theon Comp. Portsmouth.

2 bower anchors, cast steel stockless type, weight abt 7600 kgs each,
1 spare anchor, weight abt 7600 kgs. Maker: Zamech, Poland.

Cain cable, studdlink, high tensile steel K3 diam. 66 mm, length 605 m,
weight abt 59 600 kgs. Maker: Ramnäs Bruk.

Steering gear, electro-hydraulic "rotary vane" type RDC 315/70. Maker:
AEG-Schiffbau, Hamburg.

2 motors, type AJ 180 M4, 28 kW, 1770 RPM. Maker: AEG.

Hydraulic agg. made by Hydro Norma.

2 pumps, type AV PG 2606. Maker: Rexroth.

2 radar apparatuses, type 3 cm, 1620/9XB resp. 10 cm, TM 1660/12 SB.
Maker: Raytheon, Salena Spa, Italy.

1 Raytheon Interswitch Unit, type 20 R 007.

1 Decca navigator, type MK 21, made by Decca Navigator, London.

1 Loran receiver, type NCD-346/JNA-108. Maker: Japan Radio.

1 Satellite Navigator, type JLE-3100, connected to log and compass.
Maker: Japan Radio.

Radio station

Transmitter, type ST 1610 A.

Transmitter, type ST 350 BX.

Transmitter, type ST 86 B emergency.

VHF, type ME 70 and STR 15 B, placed on bridge receiving also in
the master- and deck office.

Receiver, type CR 307 A.

Receiver, type RR-1.

SSB Radiotelephone, type STR 250 B. Placed on bridge.

Full Marine Telex System (Maritex)

Equipment in radio station, are rented by Televerket, Sweden.

2 gyro compasses, type MK 37, mod. 1. Maker: Sperry Marine.

Automatic direction finder, type ADF 2200. Maker: ITT-Marine.

Echo sounding system, type EN and IS/SIMRAD. Maker: Simonsen
Radio A/S, Norway.

SAL-log, type SAL-ACCOR, made by Jungner Instrument.

Weather facsimile, type Rayfax 1200 AHR. Maker: Japan Radio.

2 searchlights on bride wings, type 37 XDS, 450 W. Maker: Noack A/S.

Window-wiper, 2 speed type. Maker: WYNN, Gloucester, England.

2 air whistles, type KT 150/110, made by Kockums, one on the signal
mast and one on the foremast.

Davit for lifeboats, 2 sets type RD 900 MC winches type F21V 675 2B1.

Maker: A/S Nor Davit, Mjølner Engineering, Bergen, Norway.

Winchmotors type AG 160 MV4, 1435/1740 RPM, 15/17 kW. Maker:
AEG.

2 motor lifeboats (glass fibre) covered type, dim. 8.00×3.00×1.20. 20
m³/706 ft³. Maker: Harding A/S, Rosendal, Norway. Motors type
2 GRG, 22 HP. Maker: Sabb Motor A/S.

Radio for lifeboats, type TRP-1. Maker: Scanti, Denmark.

5 liferafts, inflatable, type VIKING (1 for 10 pers., 4 for 25 pers.).
Maker: A/S Nordisk Gummibådsfabrik, Denmark.

Accommodation ladder, type 11, made by Marine Aluminium, Aanesen
& Co, Haugesund, Norway.

2 winches for accommodation ladder, type FVB 1023, SWL 2600 kg.
Maker: Helsingborgs Varfs AB.

1 air driven motor, type PAM 40 R, Pluto, Denmark.

CO₂ fire-fighting total flooding system in engine room and cargo holds,
87 bottles à 45 kgs. Maker: Lux Brandslukning A/S.

Fire alarm system, type HAA 100. Maker: L.M. Ericsson.

Smoke detector system, made by Lux Brandslukning A/S.

Automatic telephone and crew call system, 50-lines, type PAX/AKD 860.
Maker: L.M. Ericsson.

5 mini transceivers connected to the telephone- and intership call system.
Maker: L M Ericsson.

MS Columbialand

Brostroms Rederi AB

class: Det norske Veritas *1A1, *MV HC,
IB (+), ice class 1A

: Canada ASPPR class A

FIGURE 1: Ship Particulars and Dimensions

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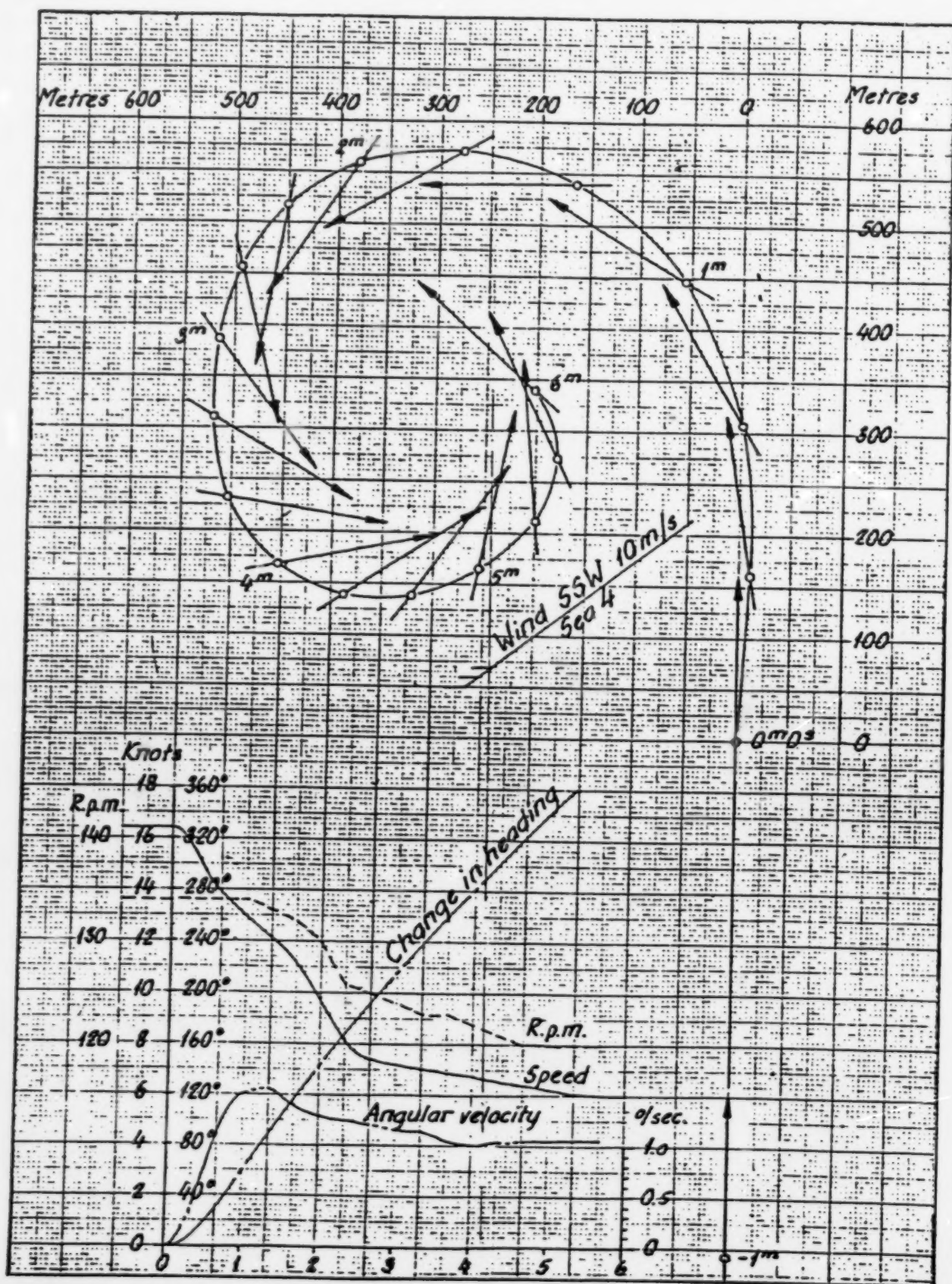


FIGURE 2: Ship Performance Data: Turning Test (Ballast), Scale 1:5000

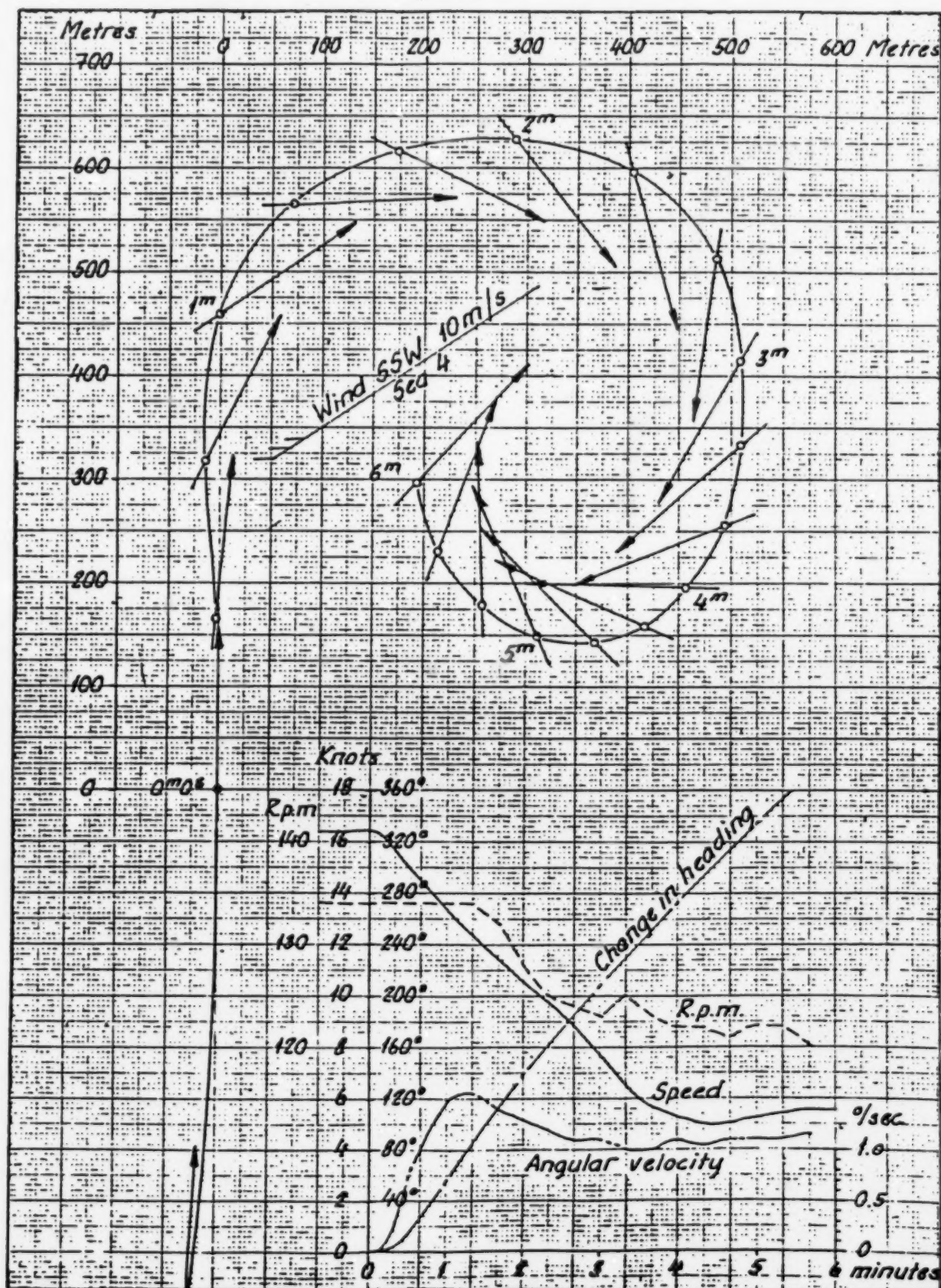


FIGURE 3: Ship Performance Data: Turning Test (Ballast), Scale 1:5000

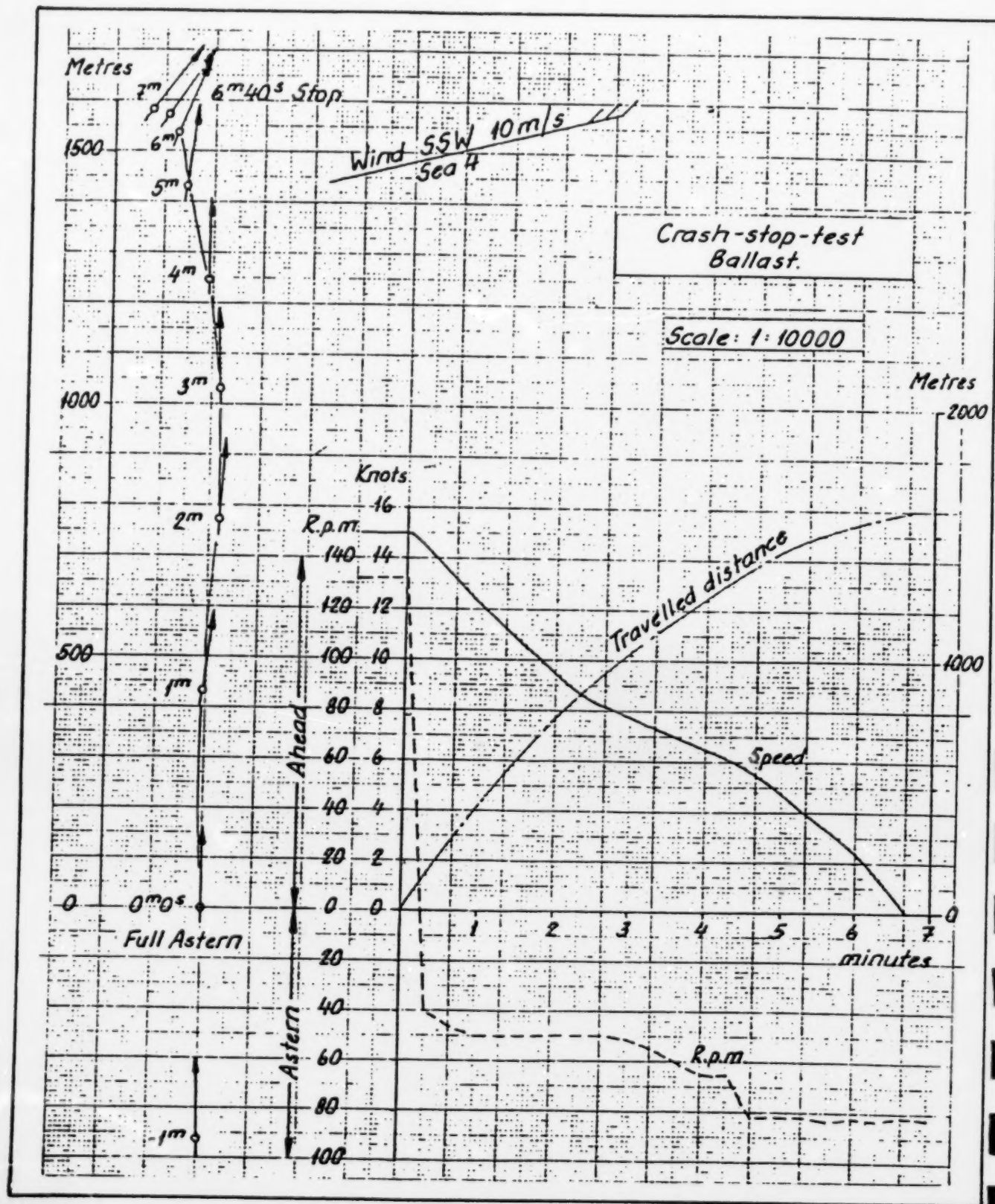


FIGURE 4: Ship Performance Data: Crash-stop Test (Ballast), Scale 1:10000

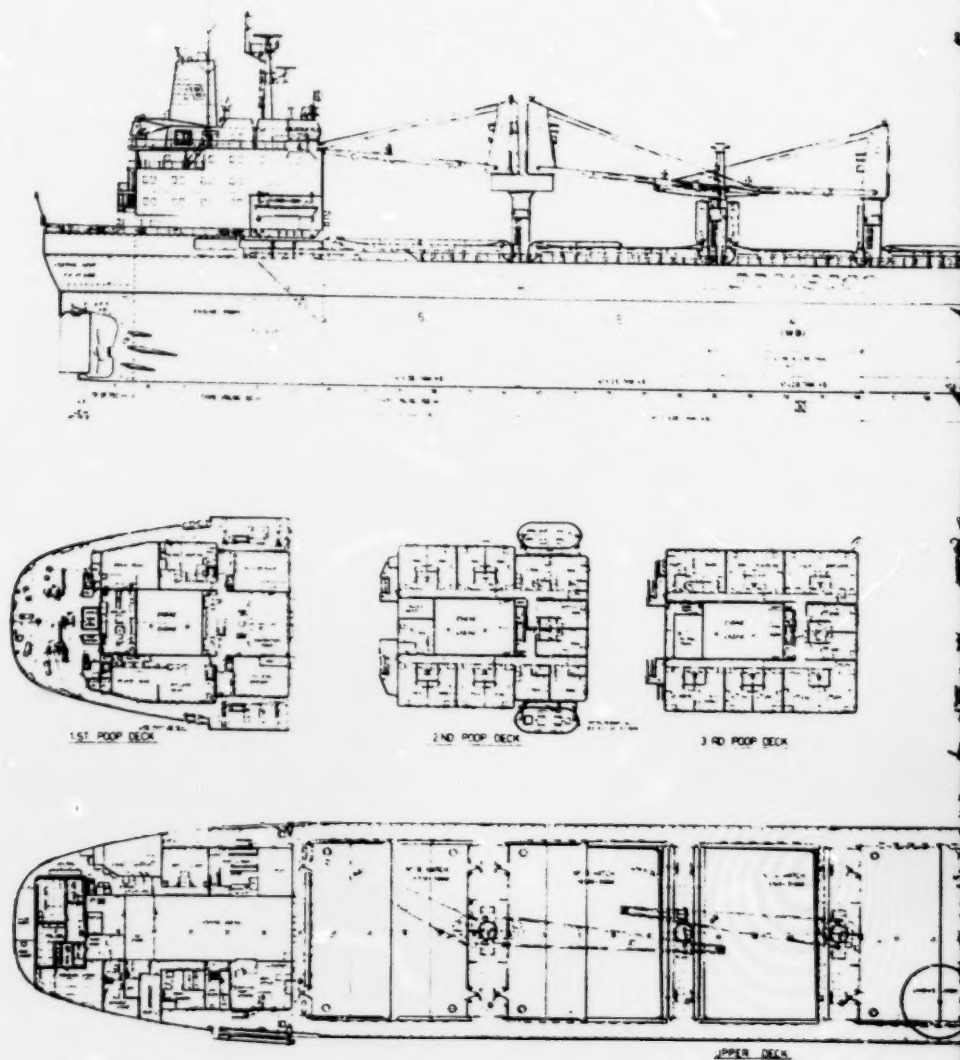
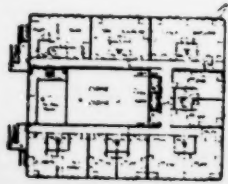
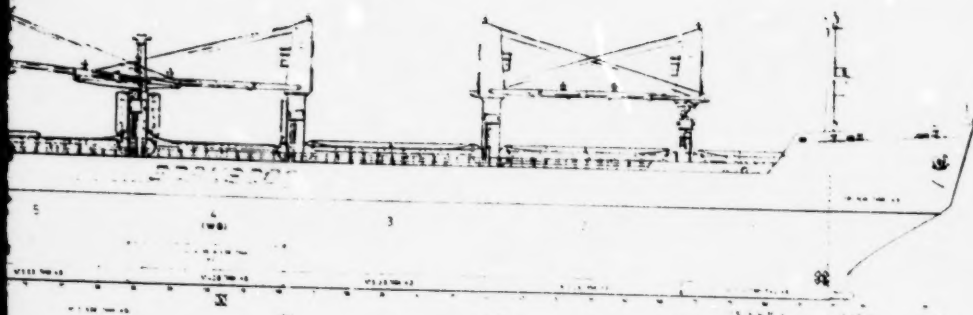
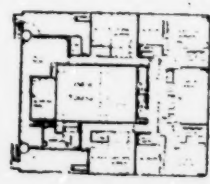


FIGURE 5: MS Columbialand - Brostroms Re

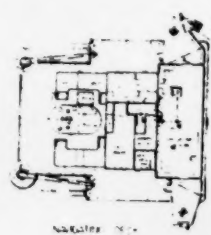
Martec Limited



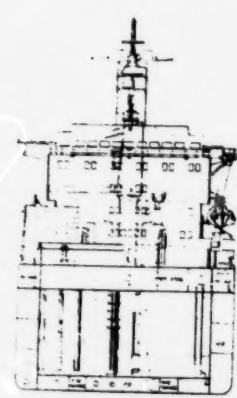
3 RD POOP DECK



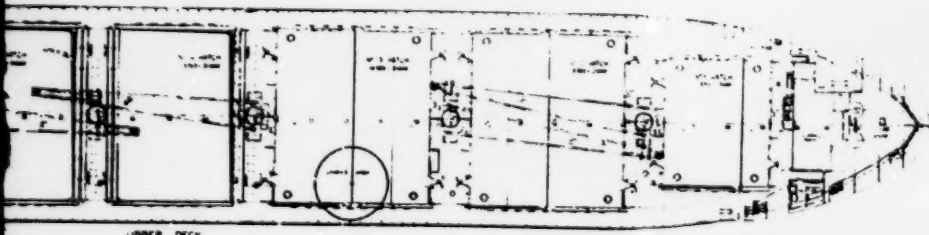
4 TH POOP DECK



NAVIGATOR DECK



TYPICAL SECTION



UPPER DECK



FORECASTLE DECK

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